Introduction to tropical fish stock assessment Part 2 - Exercises

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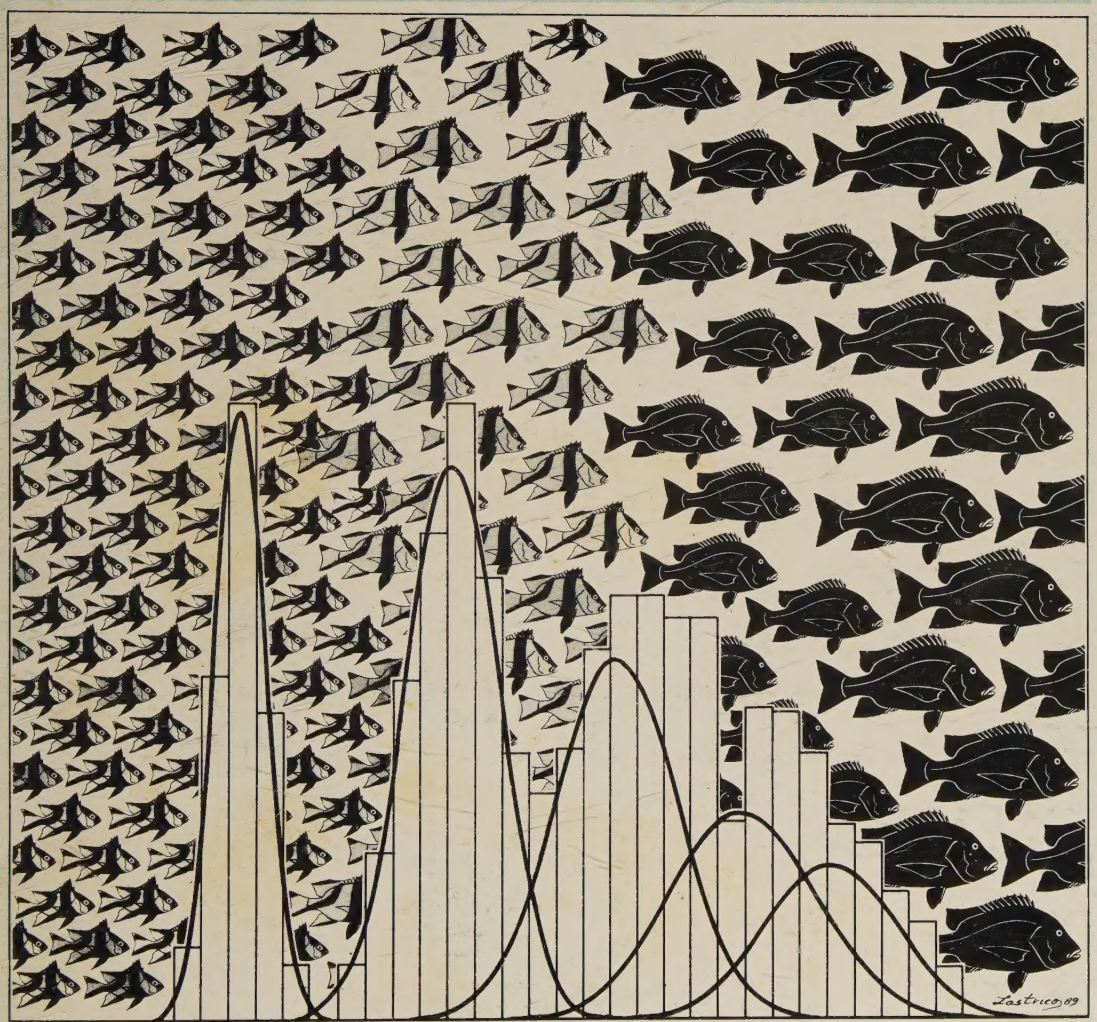

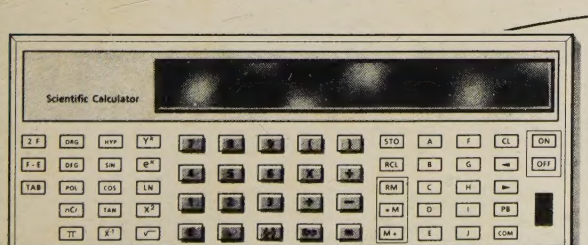

$$N_2 = N_1 \frac{1/X - F/Z}{X - F/Z}$$

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Introduction to tropical fish stock assessment Part 2 - Exercises

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Rome, 1989

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PREPARATION OF THIS DOCUMENT

This is the second part of the manual, containing a number of Exercises related to the text in Part 1 and their Solutions. The completed exercises form another example of the applications of methods explained in the manual.

The first edition of this manual was prepared by the FAO/DANIDA project "Training in fish stock assessment and fisheries research planning" (GCP/INT/392/DEN) for use in a series of regional and national training courses on fish stock assessment organized by the project from 1983 to early 1989.

In 1984 the author Per Sparre, then employed by the Danish Institute of Fisheries and Marine Research, Charlottenlund, Denmark, was asked to write this manual on the basis of lecture notes and case studies prepared by the following team of lecturers engaged in the courses:

Mr. Peder Agger of Roskilde University, Denmark, Dr. Ole Bagge, Dr. Jan Beyer, Mr. Jørgen Møller Christensen, Mr. Poul Degnbol, Mr. Henrik Gislason, Mr. Eskild Kirkegaard, Mr. Hans Lassen, Mr. Niels A. Nielsen, Mr. Per Sparre and Dr. Erik Ursin of the Danish Institute for Fisheries and Marine Research, Dr. Daniel Pauly of the International Center for Living Aquatic Resources Management and Mr. Siebren C. Venema of FAO.

The first edition was printed in July 1985 in Manila, Philippines, and distributed by the project through the Network of Tropical Fisheries Scientists of ICLARM and training courses.

The demand for copies of the manual turned out to be high and in 1986 an FAO/DANIDA project evaluation team strongly recommended it to be edited, reprinted and distributed widely.

In the mean time the project has organized three follow-up courses, where participants were assisted in preparing a scientific paper based on their own data sets, respectively in Hirtshals, Denmark (1986), Manila, the Philippines (1987) and Cochin, India (1987). These courses exposed the need for an expansion of the manual to cover assessments of migratory stocks and gear selectivity and the modification of other subjects.

Further a large number of useful comments and suggestions were received from various users of the first edition in particular the participants and local staff of the courses organized between 1985 and 1989, Dr. E.L. Olsen of the University of Papua New Guinea, Dr. S. Garcia, Chief of the Marine Resources Service, FAO and many others.

Dr. Keith Brander (Fisheries Laboratory, Lowestoft, UK) and Mr. Niek van Zalinge (FAO, Rome) were engaged by the project to review the manual, including some of the additions and they also came up with many useful suggestions and corrections.

Early 1989 it was decided to make a more thorough review of the manual and to publish it as a FAO Fisheries Technical Paper. Dr. Erik Ursin (consultant) and Siebren C. Venema (project manager) of the FAO/DANIDA project, undertook this revision in close cooperation with Per Sparre (now Fishery Resources Officer, Marine Resources Service, FAO, Rome). The figures, of which the originals were all drawn by Per Sparre, were partly revised and redrawn by Mr. Oliviero Lidonnici and a new cover was designed by Per Sparre and Paolo Lastrico (FAO). The references were reviewed by Ms. Gloria Soave and Siebren Venema and last, but not least, the text was completely retyped and rearranged by Ms. Jane Ugilt (Denmark).

Due to time constraints the text has not been reviewed by an English mother tongue editor, and we hope that you will forgive us for the occasional odd wording. Translations into French (already partly completed on the basis of the first edition by the International Center for Ocean Development, Canada), Spanish and Portuguese, are scheduled to appear in the course of 1990 or early 1991.

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ABSTRACT

A selection of methods on fish stock assessment is described in detail, with examples of calculations. Special emphasis is placed on methods applicable to tropical fisheries, i.e. those based on the analysis of length-frequencies. After a short introduction to statistics, it covers the estimation of growth parameters and mortality rates, virtual population methods (including length and age based methods), gear selectivity, the yield per recruit model of Beverton and Holt, the estimation of maximum sustainable yield using surplus production models, multispecies and multifleet problems, the assessment of migratory stocks, a discussion on the stock/recruitment relationship and the execution of demersal trawl surveys. The link between this manual and the Length Frequency Stock Assessment (LFSA) package of microcomputer programs is explained. The manual is completed with an extensive list of references (including material for further reading), a list of symbols used, a subject index and a number of exercises with solutions.

Distribution:

DANIDA
Participants at FAO/DANIDA courses on Fish Stock Assessment
Members of the Network of Tropical Fisheries Scientists
Institutes specialised in Tropical Fish Stock Assessment
Institutes of Fisheries Education
Interested National and International Organizations
Marine and Inland Selectors
FAO Regional Fishery Officers
FAO Fisheries Department
GCP/INT/392/DEN

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LIST OF SYMBOLS USED

A: Mathematical notation (general)

*	multiplication sign
/	division
ln	natural logarithm (base e = 2.7182818)
log	10 based logarithm
exp	exponential function, $\exp(x) = e^x$
$\sum_{i=1}^{n} X(i)$	sum of all values of X(i), for i from 1 to n; the sum X(1)+X(2)+...+X(n)
$\surd$ or $\sqrt{\ }$	square root
∞	infinity
Δx	delta x, a small increment of the variable x
$\max_j \{ X(j) \}$	maximum value among the elements in the set { X(j) } = { X(1),X(2),...X(j),... }
$\bar{x}$	mean value of x
x(i,j)	i,j indices of x (usually printed as $x_{i,j}$)
π	pi = 3.14159
a < b	a smaller than b
a > b	a greater than b
a => b	a greater than or equal to b

B. Statistical notation

		First introduced Section
linear regression y = a + bx		2.4
a	intercept	-
b	slope	-
x	independent variable	-
y	dependent variable	-
r	correlation coefficient	-
a'	intercept of functional regression	2.5
b'	slope of functional regression	-
n	number of observations	2.1
$\bar{x}$	mean value of x	2.1
s^2	variance	
s	standard deviation	2.1
$s/\bar{x}$	relative standard deviation or coefficient of variation	2.1
$s/\surd n$	standard error	2.1
t(f)	fractile of Student's t-distribution	2.3
f	degrees of freedom	2.3
ϵ	(epsilon) maximum relative error	2.7

C. Symbols used in formulas for fish stock assessment

		Section
a	swept area (effective path swept by a trawl)	13.5
ASP	available sum of peaks (ELEFAN)	3.5
b	constant in length-weight relationship $W = qL^b$	2.6
B	biomass	5.3
Bv	virgin (unexploited) biomass	8.3, 9.1
B/R	biomass per recruit	8.2
C	catch in numbers (VPA)	5.0
C(t,∞)	cumulated catch	4.4
C	amplitude (0-1) (ELEFAN)	3.5
CPUE	catch per unit of effort	4.3
D	number of natural deaths (VPA)	5.0
D50%	deselection, length at which 50% is not caught	6.2
dL	interval size of length	3.4
E	fishing effort	7.1
E	exploitation rate (F/Z)	8.4
ESP	explained sum of peaks (ELEFAN)	3.5
f	fishing effort (also as F)	9.0
F	fishing mortality coefficient or instantaneous rate (per time unit)	4.2
Fm	maximum fishing mortality	5.3
F-array	array of F at age, fishing pattern	5.1
I	separation index	3.5
K	curvature parameter	3.1
L	length	general
L1-L2	length class	-
L_∞ or L∞	L infinity, asymptotic length (mean length of very old fish)	3.1
L'	some length for which all fish of that length and larger are under full exploitation (lower limit of corresponding length interval)	4.5
Lc or L50%	length at which 50% of the fish is retained by the gear and 50% escape	4.5
L75% or L75	length at which 75% of the fish is retained in the gear	6.1
Lm	optimum length for being caught	6.2
m	= K/Z	8.4
M	natural mortality coefficient or instantaneous rate of natural mortality or natural mortality rate (per time unit)	4.2
MSE	Maximum Sustainable Economic Yield	5.5
MSY	Maximum Sustainable Yield	5.5
N	number of survivors (VPA)	5.0
N(t)	number of survivors of a cohort attaining age t	4.1
N(Tr)	number of recruits to the fishery	4.1
ϕ'	(phi prime), ln K + 2 * ln L_∞	3.7
q	condition factor, constant in length-weight relationship	2.6
q	catchability coefficient	4.3
R	recruitment N(Tr)	4.1
S	selection curve	6.1
S(L)	logistic curve	6.1
S.F.	selection factor	6.1
S/R	stock recruitment relationship	12.0
t	time (usually in years)	general
T	ambient temperature in °C	4.7
Tc	age at first capture (start of exploited phase)	4.1
Tm	longevity (maximum age)	4.7
Tm 50	age of massive maturation (50% of population mature)	4.7
t_o	t-zero, initial condition parameter (in years)	3.1
Tr	recruitment age	4.1
ts	summerpoint (0-1) (ELEFAN)	3.5

tw	winterpoint (0-1) (ELEFAN)		3.5
t50%	age at which 50% of the fish is retained in the gear (Thompson and Bell)	(5.3)	6.1
U	1-Lc/L		8.4
v	value (Thompson and Bell)		5.3
VPA	Virtual Population Analysis		5.0
W_∞	weight infinity, asymptotic weight (W infinity, mean weight of very old fish)		3.3
X factor	multiplication factor of F (Thompson and Bell)		5.3
Y	yield		5.3
Y/R	yield per recruit		8.2
(Y/R)'	relative yield per recruit		8.4
Z	total mortality coefficient instantaneous rate of total mortality, total mortality rate (per time unit)		4.2

17 EXERCISES

The exercises are numbered according to the numbers of the relevant sections of the manual.

Exercise 2.1 Mean value and variance

In this exercise we use part of the length frequency data on coral trout (Plectropomus leopardus) presented in Fig. 3.4.0.2. The length frequencies used for this exercise are presented in Fig. 17.2.1 . Only those in the length interval 23-29 cm are used, and assumed to belong to one cohort.

Tasks:

Read the frequencies, F(j) from Fig. A and complete the worksheet. Calculate mean, variance and standard deviation.

Worksheet 2.1

j	L(j)-L(j+1)	F(j)	$\bar{L}(j)$	$F(j)\bar{L}(j)$	$\bar{L}(j)-\bar{x}$	$F(j)(\bar{L}(j)-\bar{x})^2$
1	-				-2.968	
2	-				-2.468	
3	-				-1.968	
4	-				-1.468	
5	-				-0.968	
6	-				-0.468	
7	-				0.032	
8	26.5-27.0	6	26.75	160.50	0.532	1.698
9	27.0-27.5	2		54.50	1.032	2.130
10	27.5-28.0	2		55.50	1.532	4.694
11	28.0-28.5	2		56.50	2.032	8.258
12	28.5-29.0	1		28.75	2.532	6.411
		$\Sigma F(j)$ 31		$\Sigma F(j)\bar{L}(j)$		$\Sigma F(j)(\bar{L}(j)-\bar{x})^2$

$\bar{x}$ = s^2 = s =

Exercise 2.2 The normal distribution

This exercise consists of fitting a normal distribution to the length frequency sample from Exercise 2.1, in other words in evaluating the expression:

$$Lc(x) = \frac{n\ dL}{s\ \sqrt{2\pi}}\ \exp[\ -\ (x-\bar{x})^2/(2s^2)]$$

for a sufficient number of x-values allowing you to draw the bell-shaped curve.

For your convenience introduce the auxiliary symbols:

$$A = \frac{n\ dL}{s\ \sqrt{2\pi}} \quad \text{and} \quad B = -\ 1/(2s^2)$$

so that the formula above can be written

$$Lc(x) = A\ \exp(\ B(x-\bar{x})^2)$$

Tasks:

1) As A and B do not depend on L and as we are going to use them many times, it is convenient to calculate them separately before-hand:

$$A = \frac{n\ dL}{s\ \sqrt{2\pi}} = \text{_____} =$$

$$B = -\ 1/(2s^2) =$$

$$\bar{x} =$$

2) Calculate Lc(x) for the following values of x:

Worksheet 2.2

x	Lc(x)	x	Lc(x)
22.0		26.0	
22.5		26.5	
23.0		27.0	
23.5		27.5	
24.0		28.0	
24.5		28.5	
25.0		29.0	
25.5		29.5	

3) Draw the bell-shaped curve on Fig. 17.2.1A

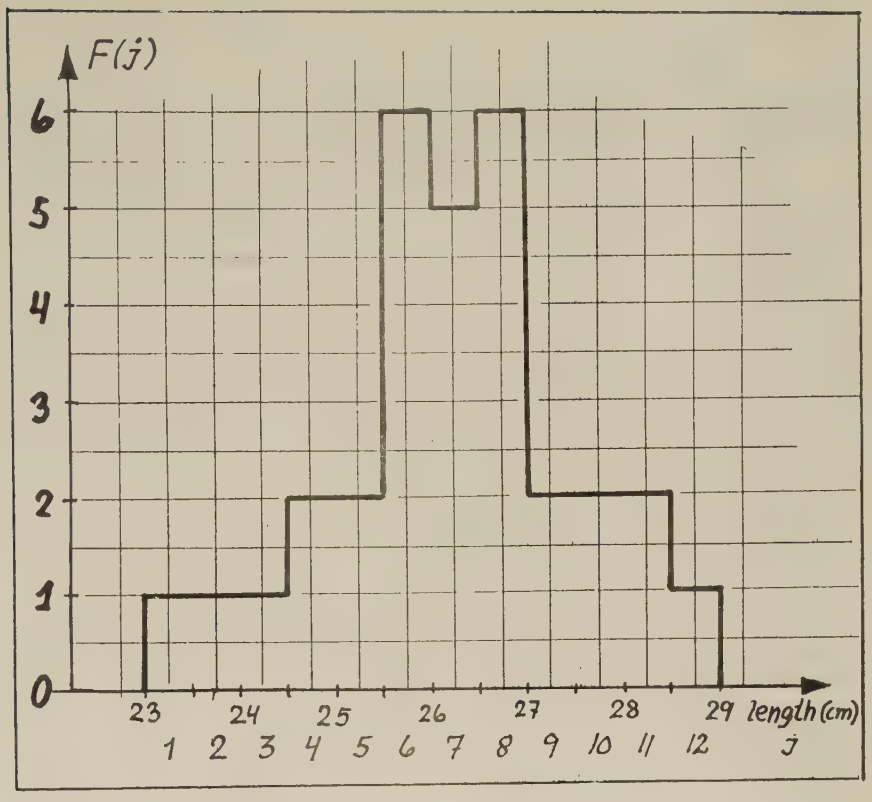


Fig. 17.2.1

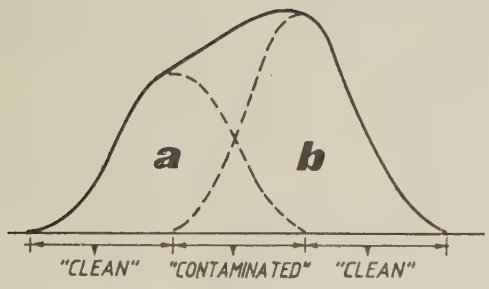


Fig. 17.2.2A

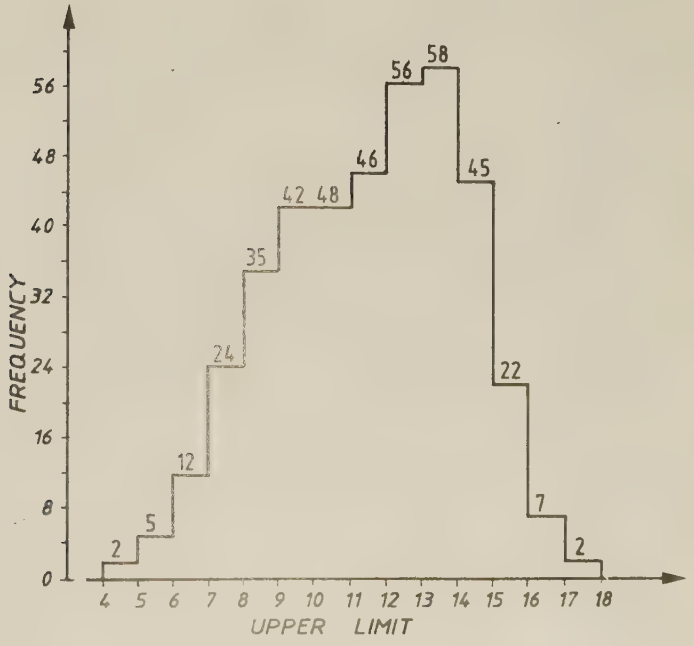


Fig. 17.2.2B

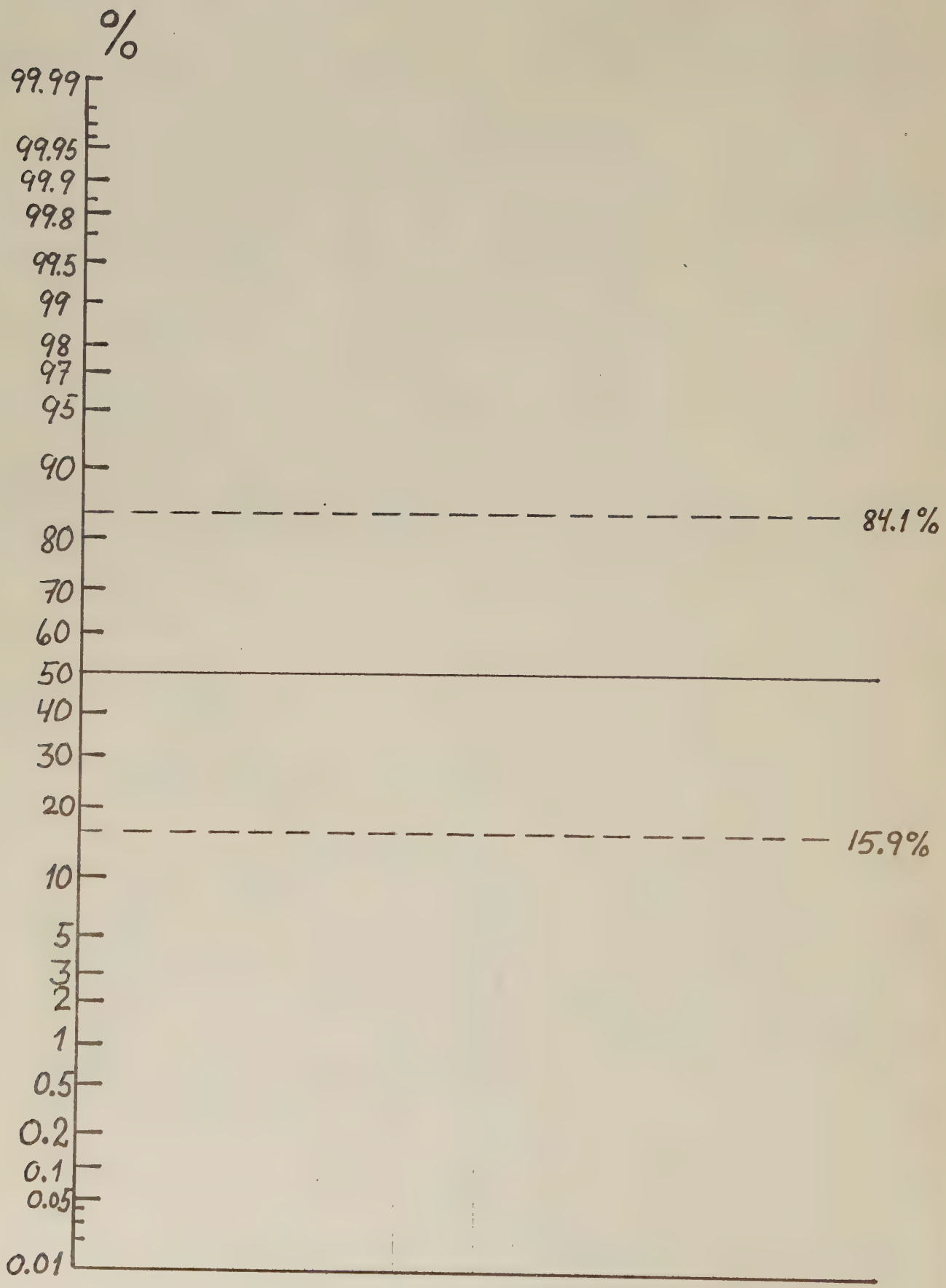

%
99.99
99.95
99.9
99.8
99.5
99
98
97
95
90
84.1%
80
70
60
50
40
30
20
15.9%
10
5
3
2
1
0.5
0.2
0.1
0.05
0.01

Fig. 17.2.2C

Exercise 2.2a Use of probability paper

Fig. 17.2.2A shows a distribution which is a mixture of two overlapping normally distributed components, "a" and "b". Fig. 17.2.2B shows a length frequency sample composed of two overlapping normally distributed components. The total sample size is 398 observations. Points belonging to a "clean area" appear as a straight line on probability paper, whereas this is not the case for a "contiminated area" (or the "overlapping area") (cf. Fig. 17.2.2A).

Tasks:

1) Using the probability paper presented in Fig. 17.2.2C, estimate the mean values and standard deviations for the two components which constitute the length frequency sample in Fig. 17.2.2B, when it is known that the number of specimens in each of the two components is the same.

2) Draw the two bell-shaped curves superimposed on Fig. 17.2.2B.

Worksheet 2.2a

			component a	component b	
Interval	F(x-0.5) x	F(x-0.5)/199	Σ F(u)/199 u<x	1 - Σ F(u)/199 u>x	a)
4- 5	2	0.010	0.010	-	
5- 6	5	0.025	0.035	-	
6- 7	12			-	
7- 8	24			-	clean
8- 9	35			-	
9-10	42			-	
10-11	42	0.211	0.814	(-0.186)	con-
11-12	46	0.231	(1.045)		ta-
12-13	56	0.281	-		mi- na- ted
13-14	58	0.291	-		
14-15	45	0.226	-	0.844	
15-16	22	0.111	-	0.955	clean
16-17	7	0.035	-	0.990	
17-18	2	0.010	-	1.000	

a) These are the cumulated frequencies backcalculated from 100%

Exercise 2.3 Confidence limits

Tasks:

Calculate the 95% confidence interval for the mean value estimated in Exercise 2.1.

Exercise 2.4 Ordinary linear regression analysis

It is often observed that the more boats participate in a fishery the less will be the catch per boat. This is not surprising when one considers the fish stock as a limited resource which all boats have to share. In Chapter 9 we shall deal with the fisheries theory behind this model.

The data shown below in the worksheet are from the Pakistan shrimp fishery (Van Zalinge and Sparre, 1986).

Tasks:

1) Draw the scatter diagram.
2) Calculate intercept and slope (use the worksheet).
3) Draw the regression line in the scatter diagram.
4) Calculate the 95% confidence limits of a and b.

Worksheet 2.4

year	i	number of boats x(i)	$x(i)^2$	catch per boat per year y(i)	$y(i)^2$	x(i) * y(i)
1971	1	456		43.5		19836.0
1972	2	536		44.6		23905.6
1973	3	554		38.4		21273.6
1974	4	675		23.8		16065.0
1975	5	702		25.2		17690.4
1976	6	730	532900	30.5	930.25	
1977	7	750	562500	27.4	750.76	
1978	8	918	842724	21.1	445.21	
1979	9	928	861184	26.1	681.21	
1980	10	897	804609	28.9	835.21	
Total		7146		309.5		211099.5

$\bar{x}$ = $\bar{y}$ =

$\frac{1}{n}(\Sigma x)^2$ = $\Sigma x^2 - \frac{1}{n}(\Sigma x)^2$ =

$\frac{1}{n}(\Sigma y)^2$ = $\Sigma y^2 - \frac{1}{n}(\Sigma y)^2$ =

$\frac{1}{n}(\Sigma x)(\Sigma y)$ =

(Worksheet 2.4)

$s_x^2 = \frac{1}{n-1} [\Sigma x^2 - \frac{1}{n} (\Sigma x)^2]$ $\quad s_x =$

$s_y^2 = \frac{1}{n-1} [\Sigma y^2 - \frac{1}{n} (\Sigma y)^2] =$ $\quad s_y =$

$s_{xy} = \frac{1}{n-1} [\Sigma xy - \frac{1}{n} (\Sigma x)(\Sigma y)] =$

Slope: $b = \frac{s_{xy}}{s_x^2} =$ $\quad$ Intercept: $a = \bar{y} - b\bar{x} =$

Variance of b:

$s_b^2 = \frac{1}{n-2} [(s_y/s_x)^2 - b^2] =$ $\quad s_b =$

Variance of a:

$s_a^2 = s_b^2 (\frac{n-1}{n} s_x^2 + \bar{x}^2) =$ $\quad s_a =$

Students distribution: $t(n-2) =$

Confidence limits:

$b - s_b * t(n-2),\ b + s_b * t(n-2) = [\qquad , \qquad]$

$a - s_a * t(n-2),\ a + s_a * t(n-2) = [\qquad , \qquad]$

Exercise 2.5 The correlation coefficient

Refer to Exercise 2.4. Does the correlation coefficient make sense in the example of catch per boat regressed on number of boats? Consider which of the variables is the natural candidate as independent variable. Can we (in principle) decide in advance on the values of one of them?

Tasks:

Irrespective of your findings in the first part of the exercise carry out the calculation of the 95% confidence limits of r.

Exercise 2.6 Linearizing transformations, the Bhattacharya plot

Tasks:

1) Use the Bhattacharya plot (worksheet) to solve Exercise 2.2a and compare the results with those obtained using probability paper.

2) Draw the plots.

3) Formulate the conditions for:

   $\bigwedge \ln F(z) > 0$

   $\bigwedge \ln F(z) < 0$

Worksheet 2.6

interval	x	F(x)	ln F(x)	/\ ln F(z)	z = x+dL/2
4 - 5	4.5	2	0.693		
				0.916	5
5 - 6	5.5	5	1.609		
				0.875	6
6 - 7	6.5	12			
					7
7 - 8	7.5	24			
8 - 9	8.5	35			
9 -10	9.5	42			
10-11	10.5	42			
11-12	11.5	46			
12-13	12.5	56			
13-14	13.5	58			
14-15	14.5	45			
15-16	15.5	22	3.091		
				-1.145	16
16-17	16.5	7	1.946		
				-1.253	17
17-18	17.5	2	0.693		

Exercise 2.8 Stratified random sampling versus simple random sampling and proportional sampling

This exercise illustrates the gain in precision obtained from stratification. Use Table 2.8.2.

Tasks:

1) Estimate the variance of the mean landing $\bar{Y}$ from three different sampling methods, when the total sample size is n = 20, using the worksheets.

   a) Simple random sampling
   b) Proportional sampling: a sample of 20% from each stratum

Worksheet 2.8 for a) and b)

stratum j	s(j)	$s(j)^2$	N(j)	$\sum_i Y(j,i)^2$	$\sum_i Y(j,i)$
1 large					
2 medium					
3 small					
Total:					

$$\text{Total } s^2 = \frac{\Sigma\ \Sigma\ Y(j,i)^2 - (1/N)\ [\Sigma\ \Sigma\ Y(j,i)]^2}{N - 1} =$$

$$\text{---------------------------------} =$$

as defined by Eq. 2.1.3.

a) Simple random sampling

$$\text{VARran}(\bar{Y}) = \frac{s^2}{n} * \frac{N - n}{N} =$$

b) Proportional sampling

$$\text{VARprop}(\bar{Y}) = \frac{1}{N^2} \sum_{j=1}^{3} \frac{N(j)(N(j)-n(j))}{n(j)}\ s(j)^2 =$$

c) Optimum stratified sampling

$$\text{VARopt}(\bar{Y}) = \frac{1}{N^2} \sum_{j=1}^{3} \frac{N(j)\ (N(j)-n(j))}{n(j)}\ s(j)^2$$

Worksheet 2.8 for c)

stratum	$s(j) * N(j)$	$\frac{s(j) * N(j)}{\Sigma s(j) * N(j)}$	$n \frac{s(j) * N(j)}{\Sigma s(j) * N(j)} = n(j)$
1 large			
2 medium			
3 small			
total:		1.00	n = 20

2) Calculate the standard deviations and compare the allocations per stratum.

	random	proportional	optimum
$s = \sqrt{VAR}$			
allocation per stratum			
1 large			
2 medium			
3 small			

Exercise 3.1 The von Bertalanffy growth equation

The growth parameters of the Malabar blood snapper (Lutjanus malabaricus) in the Arafura Sea were reported by Edwards (1985) as:

$K = 0.168$ per year
$L_\infty = 70.7$ cm (standard length)
$t_o = 0.418$ years

Edwards also estimated the standard length/weight relationship for Lutjanus malabaricus:

$$W = 0.041\ L^{2.842}$$ (weight in g and standard length in cm)

as well as the relationship between standard length (S.L.) and total length (T.L.):

$$T.L. = 0.21 + 1.18 * S.L.$$

Tasks:

Complete the worksheet and draw the following three curves:

1) Standard length as a function of age
2) Total length as a function of age
3) Weight as a function of age

Worksheet 3.1

age	standard length	body weight	total length	age	standard length	body weight	total length
0.5				8			
1.0				9			
1.5				10			
2				12			
3				14			
4				16			
5				(do not use ages above 16 in the graph)			
6							
7				20			
				50			

Exercise 3.2.1 **Data from age readings and length compositions (age/length key)**

Consider Table 3.2.1.1 (age/length key) and suppose we caught a total of 2400 fish of the species in question during the cruise from which this age/length key was obtained and that only 439 specimens of Table 3.2.1.1 were aged. The remaining fish were all measured for length. To reduce the computational work of the exercise only a part (386 fish) of this length frequency sample is used. This part is shown in the worksheet.

Tasks:

Estimate how many of these 386 fish belonged to each of the six cohorts listed in Table 3.2.1.1, by completing the worksheet.

Worksheet 3.2.1

cohort length interval	1982 S	1981 A	1981 S	1980 A	number in length sample	1982 S	1981 A	1981 S	1980 A
35-36	0.800	0.200	0	0	53	42.4	10.6	0	0
36-37	0.636	0.273	0.091	0	61	38.8	16.7	5.6	0
37-38					49				
38-39					52				
39-40					70				
40-41					52				
41-42	0.222	0.444	0.222	0.111	49	10.9	21.8	10.9	5.4
				total	386	187.2	133.8		

Exercise 3.3.1 The Gulland and Holt plot

Randall (1962) tagged, released and recaptured ocean surgeon fish (Acanthurus bahianus) near the Virgin Islands. Data of 11 of the recaptured fish are shown in the worksheet, in the form of their length at release (column B) and at recapture (column C) and the length of the time between release and recapture (column D).

Tasks:

1) Estimate K and L_∞ for the ocean surgeon fish using the Gulland and Holt plot.

2) Calculate the 95% confidence limits of the estimate of K.

Worksheet 3.3.1

A	B	C	D	E	F
fish no.	$L(t)$ cm	$L(t+\Delta t)$ cm	Δt days	$\frac{\Delta L}{\Delta t}$ cm/year	$\frac{L(t)+L(t+\Delta t)}{2}$ cm
1	9.7	10.2	53		
2	10.5	10.9	33		
3	10.9	11.8	108		
4	11.1	12.0	102		
5	12.4	15.5	272		
6	12.8	13.6	48		
7	14.0	14.3	53		
8	16.1	16.4	73		
9	16.3	16.5	63		
10	17.0	17.2	106		
11	17.7	18.0	111		

a (intercept) = b (slope) =

K = L_∞ =

$sb^2 = \frac{1}{n-2}\left[(sy/sx)^2 - b^2\right]$ =

sb = t(n-2) =

Confidence interval of K:

Exercise 3.3.2 **The Ford-Walford plot (and Gulland and Holt plot)**

Postel (1955) reports the following length/age relationship for Atlantic yellowfin (Thunnus albacares) off Senegal:

age (years)	Fork length (cm)
1	35
2	55
3	75
4	90
5	105
6	115

Tasks:

Estimate K and L_∞ using the Ford-Walford plot and the Gulland and Holt plot.

Worksheet 3.3.2

method	FORD-WALFORD		GULLAND AND HOLT	
t	L(t)	L(t+/\t)	/\L//\t	$\bar{L}$
1				
2				
3				
4				
5				
a (intercept)				
b (slope)				
$sb^2 = \frac{1}{n-2}[(sy/sx^2) - b^2]$				
confidence limits of b				
K				
L_∞				

Exercise 3.3.3 The von Bertalanffy plot

Cassie (1954) presented the length frequency sample of 256 seabreams (Chrysophrys auratus) shown in the figure. He resolved this sample into normally distributed components (similar to Fig. 3.2.2.2) using the Cassie method (cf. Section 3.4.3) and found the following mean lengths for four age groups (compare Fig. 17.3.3.3):

A	B	C	D
age group	mean length (in.)	$\Delta L/\Delta t$	$\bar{L}$
0	3.22		
		2.11	4.28
1	5.33		
		2.29	6.48
2	7.62		
		2.12	8.68
3	9.74		

Note: a Gulland and Holt plot gives (cf. Columns C and D): K = -0.002 and L_∞ = -950 inches, which makes no sense whatsoever.

Tasks:

1) Estimate K from the von Bertalanffy plot.
2) Why does it not make sense to ask you to estimate t_o?

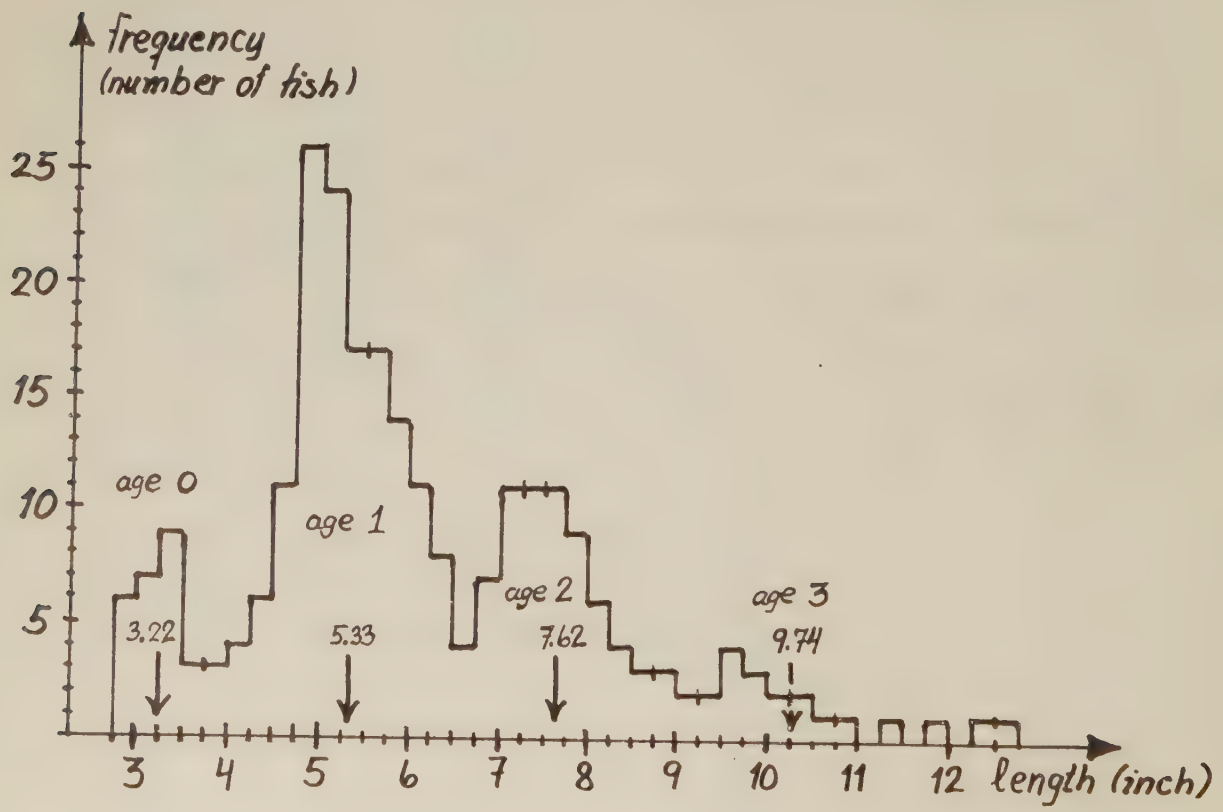


Fig. 17.3.3.3

Exercise 3.3.6 **The weight converted von Bertalanffy growth equation**

Pauly (1980) determined the following parameters for the ponyfish or slipmouth (*Leiognathus splendens*) from western Indonesia:

L_∞ = 14 cm K = 1.0 per year
q = 0.02332 t_o = -0.2 year

Tasks:

Complete the worksheet and draw the length and the weight converted von Bertalanffy growth curves.

Worksheet 3.3.6

age t	length L(t)	weight w(t)	age t	length L(t)	weight w(t)
0			0.9		
0.1			1.0		
0.2			1.2		
0.3			1.4		
0.4			1.6		
0.5			1.8		
0.6			2.0		
0.7			2.5		
0.8			3.0		

Worksheet 3.4.1b

A	B	C	D	E	F	G	H	I
interval	N2+	ln N2+	/\ln N2+	L	/\ln N2c	ln N2c	N2	N3+
.....								
10.75-11.75	14.5	2.674	-	10.75	-	-	14.5	0
11.75-12.75s	41	3.714	1.039*	11.75	-	-	41	0
12.75-13.75	125	4.828s	1.115*	12.75	-	-	125	0
13.75-14.75	135s	4.905	0.077*	13.75	0.238	5.066	135	0
14.75-15.75	102	4.625	-0.280*	14.75	-0.262	4.804	102	0
15.75-16.75	131	4.875	0.250	15.75	-0.761	4.043	57.0	74.0
16.75-17.75	106	4.663	-0.212	16.75	-1.261	2.782	16.2	89.8
17.75-18.75	86	4.454	-0.209	17.75	-1.760	1.022	2.8	83.2
18.75-19.75	59	4.078	-0.377	18.75	-2.260	-1.038	0.3	58.7
19.75-20.75	43	3.761	-0.316	19.75	-2.759	-3.997	0.0	43
20.75-21.75	45	3.807	0.045	20.75	-	-	-	45
21.75-22.75	56	4.025	0.219	21.75	-	-	-	56
.....								
Total							493.8	

a (intercept) = 7.11 b (slope) = - 0.500

$\bar{L}2 = -a/b =$ 14.2 $s = \sqrt{-1/b} =$ 1.41

Worksheet 3.4.1c

A	B	C	D	E	F	G	H	I
interval	N3+	ln N3+	/\ln N3+	L	/\ln N3c	ln N3c	N3	N4+
.....								
15.75-16.75	74.0	-	-	15.75	-	-	74	0
16.75-17.75s	89.8	4.498	0.194*	16.75	-	-	89.9	0
17.75-18.75	83.2	4.421s	-0.076*	17.75	-	-	83.2	0
18.75-19.75	58.7s	4.072	-0.348*	18.75	-0.225	4.196	58.7	0
19.75-20.75	43	3.761	-0.312*	19.75	-0.404	3.792	43.0	0
20.75-21.75	45	3.807	0.046	20.75	-0.583	3.209	24.8	20.2
21.75-22.75	56	4.025	0.219	21.75	-0.762	2.447	11.6	44.4
22.75-23.75	20	2.996	-1.030	22.75	-0.941	1.506	4.5	15.5
23.75-24.75	8	2.079	-0.916	23.75	-1.120	0.386	1.5	6.5
24.75-25.75	3	1.099	-0.981	24.75	-1.299	-0.913	0.4	2.6
25.75-26.75	1	0	-1.099	25.75	-	-	-	1
Total							391.5	

a (intercept) = 3.13 b (slope) = - 0.179

$\bar{L}3 = -a/b =$ 17.5 $s = \sqrt{-1/b} =$ 2.36

*) points used in the regression analysis

Exercise 3.4.1 Bhattacharya's method

Weber and Jothy (1977) presented the length frequency sample of 1069 threadfin breams (Nemipterus nematophorus) shown in Fig. 17.3.4.1A. These fish were caught during a survey from 29 March to 1 May, 1972, in the South China Sea bordering Sarawak. The lengths measured are total lengths from the snout to the tip of the lower lobe of the caudal fin.

Figs. 17.3.4.1B and 17.3.4.1C show the Bhattacharya plot for the data in Fig. 17.3.4.1A, where B is based on the original data in 5 mm length intervals and C on the same data regrouped in 1 cm intervals. You should proceed with Figure C for two reasons: 1) because it appears easier to see a structure in Fig. C than in Fig. B and 2) because the calculation work is much reduced.

Tasks:

1) Resolve the length frequency sample (1 cm groups, Fig. C) into normally distributed components and estimate thereby mean length and standard deviations for each component. Use the four worksheets and plot the regression lines.

2) Estimate L_∞ and K using a Gulland and Holt plot. Draw the plot.

3) Do you think the analysis could have been improved by using Fig. B (5 mm length groups) instead of Fig. C (1 cm groups)?

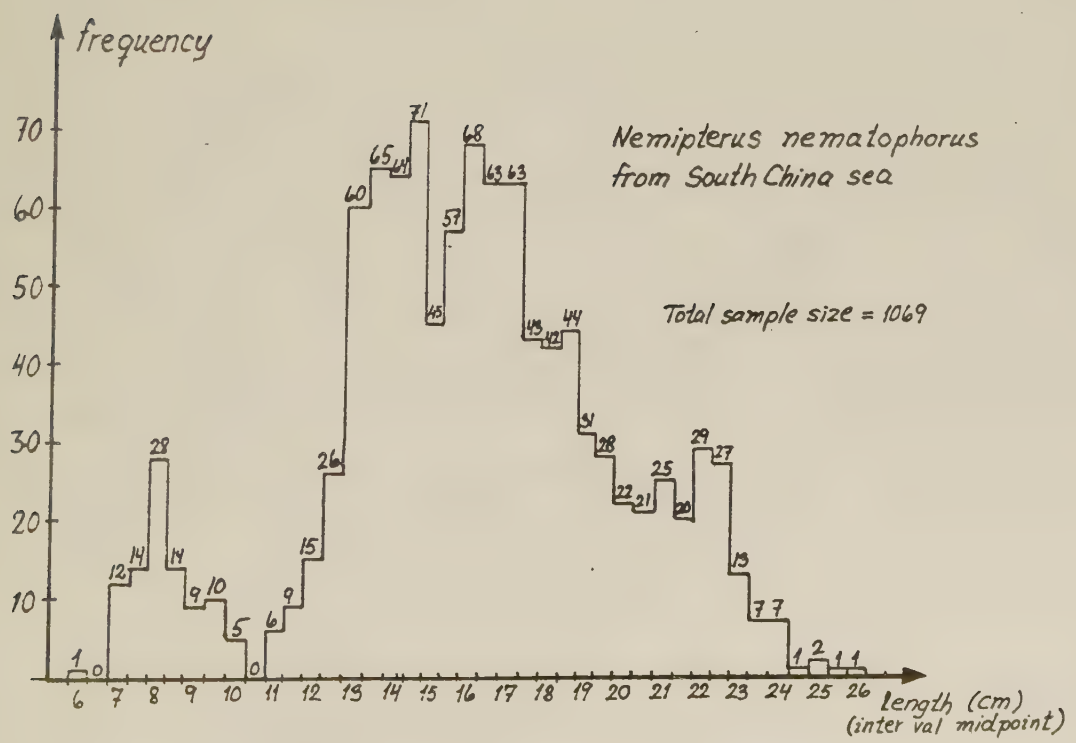


Fig. 17.3.4.1A

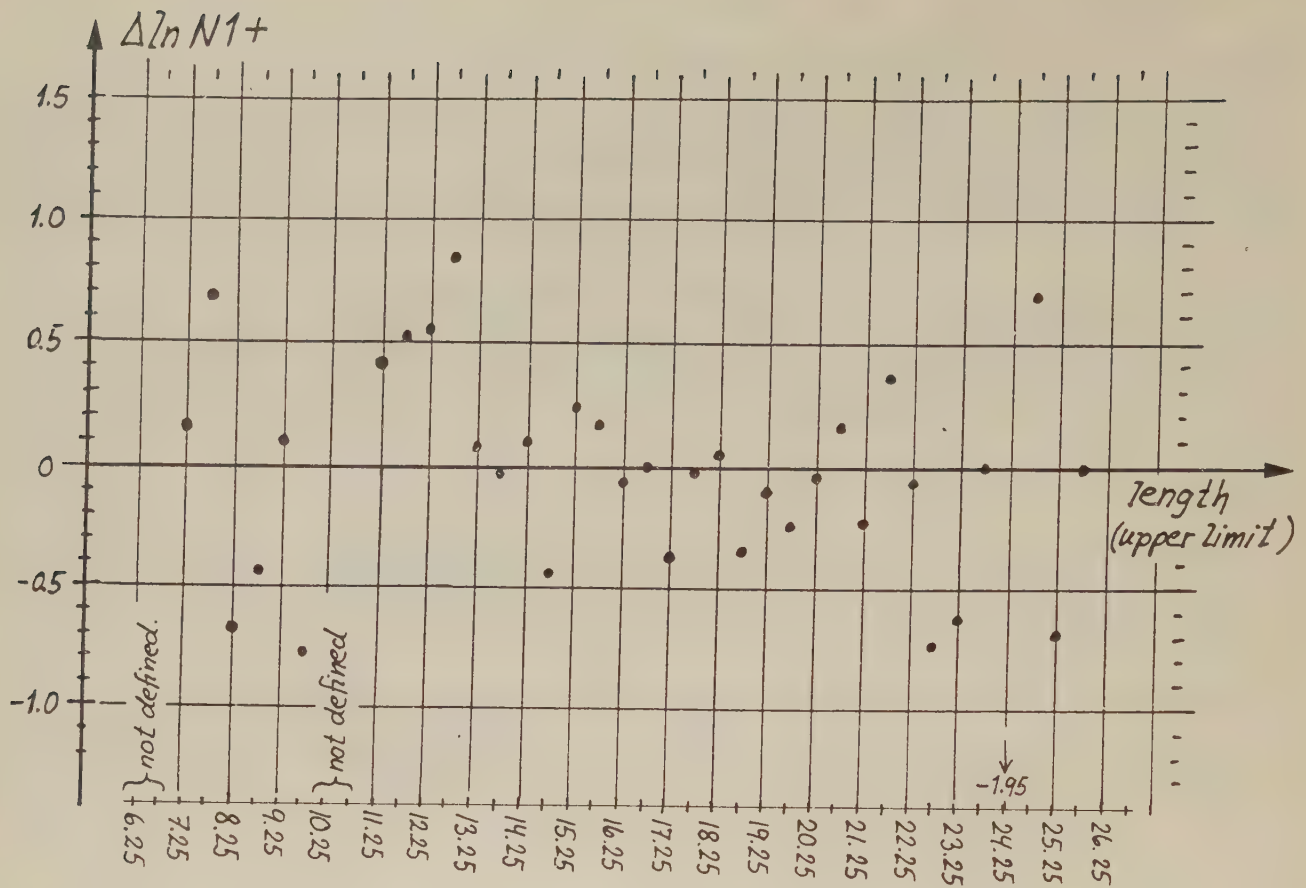


Fig. 17.3.4.1B

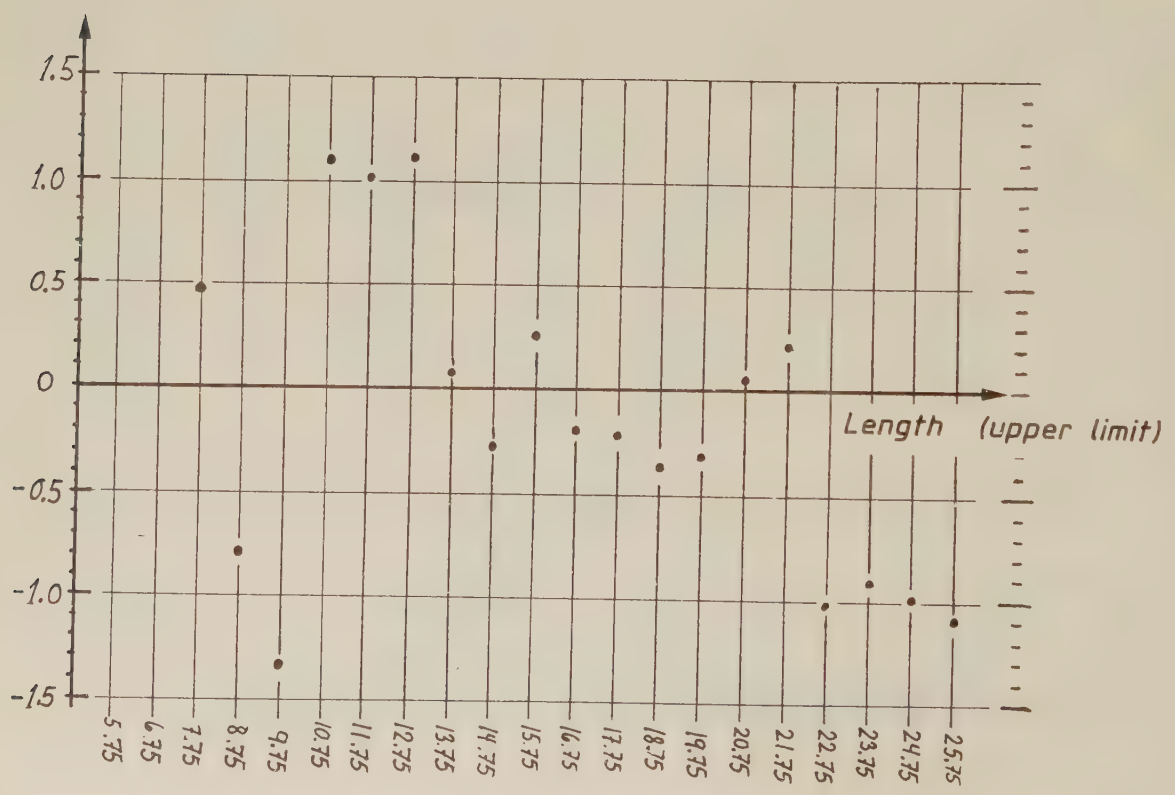


Fig. 17.3.4.1C

Worksheet 3.4.1a

A	B	C	D	E	F	G	H	I
Interval	N1+	ln N1+	/\ln N1+	L	/\ln N1c	ln N1c	N1	N2+
5.75- 6.75	1	0	-	-	-	-	1	0
6.75- 7.75s	26	3.258	(3.258)	6.75	1.262	("clean")	26	0
7.75- 8.75	42	3.738	0.480	7.75	0.354	3.738	42	0
8.75- 9.75	19s	2.944	-0.793	8.75	-0.554	3.183	19	0
9.75-10.75	5			9.75				
10.75-11.75	15			10.75				
11.75-12.75	41			11.75				
12.75-13.75	125			12.75				
13.75-14.75	135			13.75				
14.75-15.75	102			14.75				
15.75-16.75	131			15.75				
16.75-17.75	106			16.75				
17.75-18.75	86			17.75				
18.75-19.75	59			18.75				
19.75-20.75	43			19.75				
20.75-21.75	45			20.75				
21.75-22.75	56			21.75				
22.75-23.75	20			22.75				
23.75-24.75	8			23.75				
24.75-25.75	3			24.75				
25.75-26.75	1			25.75				
Total	1069							

a (intercept) = b (slope) =

$\bar{L}1 = -a/b$ = $s = \sqrt{-1/b}$ =

Worksheet 3.4.1b

A	B	C	D	E	F	G	H	I
Interval	N2+	ln N2+	/\ln N2+	L	/\ln N2c	ln N2c	N2	N3+
5.75- 6.75								
6.75- 7.75				6.75				
7.75- 8.75				7.75				
8.75- 9.75				8.75				
9.75-10.75				9.75				
10.75-11.75				10.75				
11.75-12.75				11.75				
12.75-13.75				12.75				
13.75-14.75				13.75				
14.75-15.75				14.75				
15.75-16.75				15.75				
16.75-17.75				16.75				
17.75-18.75				17.75				
18.75-19.75				18.75				
19.75-20.75				19.75				
20.75-21.75				20.75				
21.75-22.75				21.75				
22.75-23.75				22.75				
23.75-24.75				23.75				
24.75-25.75				24.75				
25.75-26.75				25.75				
Total								

a (intercept) = b (slope) =

$\tilde{L}2 = -a/b$ = $s = \sqrt{-1/b}$ =

Worksheet 3.4.1c

A	B	C	D	E	F	G	H	I
Interval	N3+	ln N3+	/\ln N3+	L	/\ln N3c	ln N3c	N3	N4+
5.75- 6.75								
6.75- 7.75				6.75				
7.75- 8.75				7.75				
8.75- 9.75				8.75				
9.75-10.75				9.75				
10.75-11.75				10.75				
11.75-12.75				11.75				
12.75-13.75				12.75				
13.75-14.75				13.75				
14.75-15.75				14.75				
15.75-16.75				15.75				
16.75-17.75				16.75				
17.75-18.75				17.75				
18.75-19.75				18.75				
19.75-20.75				19.75				
20.75-21.75				20.75				
21.75-22.75				21.75				
22.75-23.75				22.75				
23.75-24.75				23.75				
24.75-25.75				24.75				
25.75-26.75				25.75				
Total								

a (intercept) = b (slope) =

$\check{L}3 = -a/b$ = $s = \sqrt{-1/b}$ =

Worksheet 3.4.1d

A	B	C	D	E	F	G	H	I
Interval	N4+	ln N4+	/\ln N4+	L	/\ln N4c	ln N4c	N4	N5+
5.75- 6.75								
6.75- 7.75				6.75				
7.75- 8.75				7.75				
8.75- 9.75				8.75				
9.75-10.75				9.75				
10.75-11.75				10.75				
11.75-12.75				11.75				
12.75-13.75				12.75				
13.75-14.75				13.75				
14.75-15.75				14.75				
15.75-16.75				15.75				
16.75-17.75				16.75				
17.75-18.75				17.75				
18.75-19.75				18.75				
19.75-20.75				19.75				
20.75-21.75				20.75				
21.75-22.75				21.75				
22.75-23.75				22.75				
23.75-24.75				23.75				
24.75-25.75				24.75				
25.75-26.75				25.75				
Total								

a (intercept) = b (slope) =

$\bar{L}4 = -a/b$ = $s = \sqrt{-1/b}$ =

Exercise 3.4.2 Modal progression analysis

Fig. 17.3.4.2A shows a time series over twelve months of ponyfish (Leiognathus splendens) from Manila Bay, Philippines, 1957-58. (Data from Tiews and Caces-Borja, 1965; figure redrawn from Ingles and Pauly, 1984). The numbers at the right hand side of the bar diagram indicate the sample sizes, while the height of the bars represents the percentages of the total number per length group.

Fig. 17.3.4.2B shows a time series over six samples of mackerel, (Rastrelliger kanagurta) from Palawan, Philippines, 1965. (Data from Research Division, BFAR, Manila; figure redrawn from Ingles and Pauly, 1984).

Tasks:

1) Fit by eye growth curves to these two time series, trying to follow the modal progression (as was done in Fig. 3.4.2.5). (Start by fitting a straight line and then add some curvature to it, but do not be too particular about it. Actually one should have carried out a Bhattacharya or similar analysis for each sample, but because of the amount of work involved in that approach, we take the easier, but less dependable, eye fit. This exercise aims at illustrating only the principles of modal progression analysis - not the exact procedure).

2) Read from the eye-fitted growth curves pairs of (T,L) = (time of sampling, length), and use the Gulland and Holt plot to estimate $\dot{K}$ and L_∞. Assume that the samples were taken on the first of the month. Read for Leiognathus splendens only the length for the samples indicated by "*" in Fig. A, as the figure is too small for a precise reading of each month. Use the worksheet.

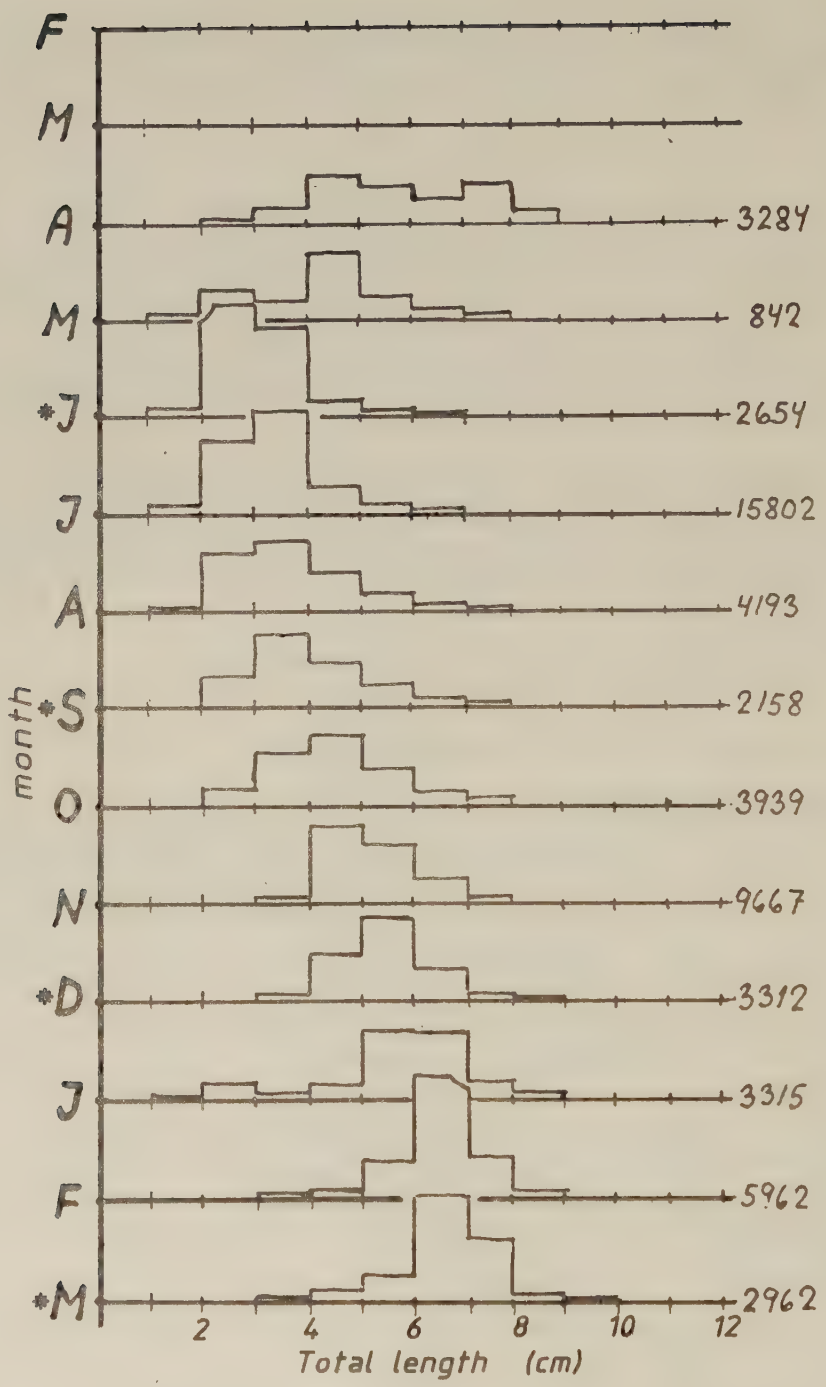
3) Use the von Bertalanffy plot to estimate t_o.

Worksheet 3.4.2

Leiognathus splendens:

		GULLAND AND HOLT PLOT		VON BERTALANFFY PLOT	
Time of sampling	L(t)	$\Delta L/\Delta t$	$\bar{L}$	t	$-\ln(1 - L/L_\infty)$
1 June					
1 Sep.					
1 Dec.					
1 March					
a (intercept)					
b (slope, K)					
-a/b		L_∞ =		t_o =	

L(t) = [1 - exp(- (t -))]



*) read length

Fig. 17.3.4.2A

Rastrelliger kanagurta:

		GULLAND AND HOLT PLOT		VON BERTALANFFY PLOT	
Time of sampling	L(t)	$\Delta L/\Delta t$	$\bar{L}$	t	$-\ln(1 - L/L_\infty)$
1 Feb.					
1 March					
1 May					
1 June					
1 July					
1 August					
a (intercept)					
b (slope, K)					
-a/b		L_∞ =		t_o =	

L(t) = [1 - exp(- (t -))]

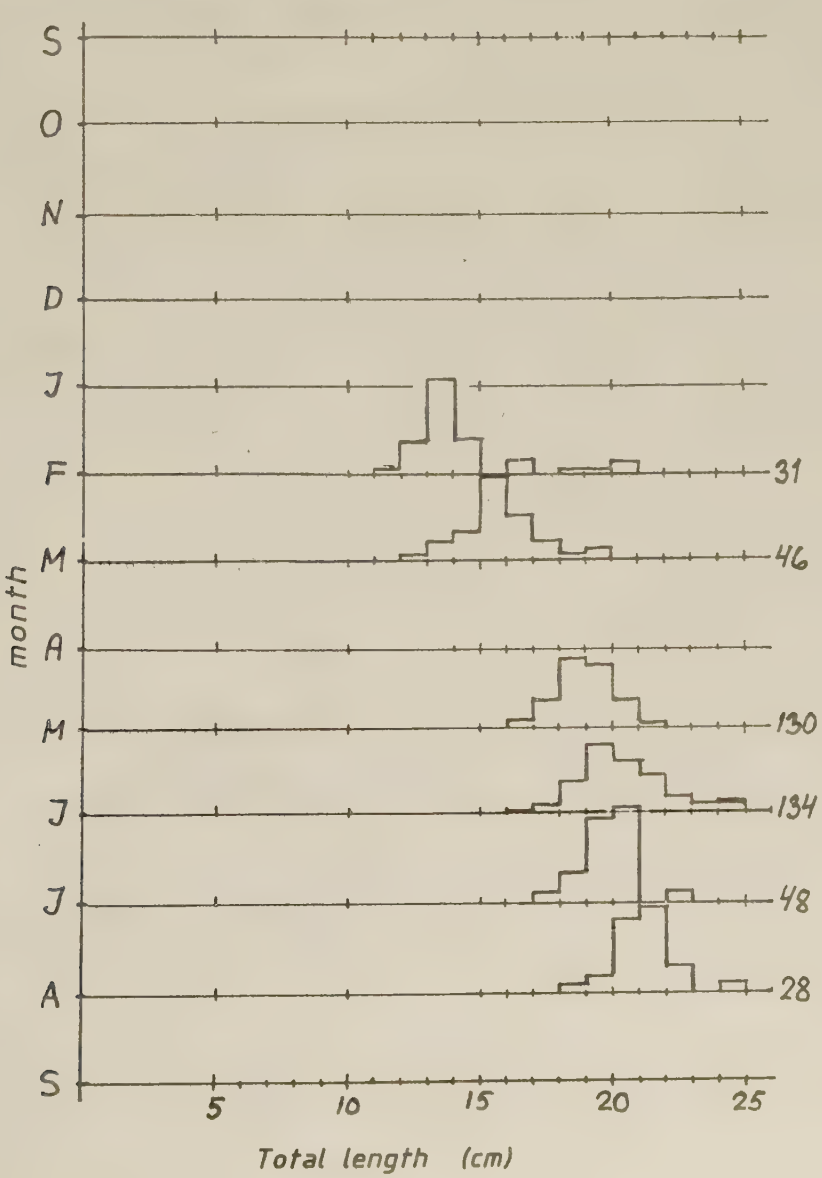


Fig. 17.3.4.2B

Exercise 3.5.1 ELEFAN I

This exercise aims at explaining the details of the length frequency restructuring process. Fig. 17.3.5.1A shows a (hypothetical) length frequency sample, where the line shows the moving average. The worksheet table shows the calculation procedure and some results. Further explanations are given below for each step of the procedure.

Tasks:

1) Fill in the missing figures in the worksheet table.

2) Draw the bar diagram of the restructured data on the worksheet figure (B).

Worksheet 3.5.1

RESTRUCTURING OF LENGTH FREQUENCY SAMPLE

mid-lgt. L	orig. freq. FRQ(L)	STEP 1 MA(L)	STEP 2 FRQ/MA	STEP 3 FRQ/MA/M-1	STEP 4a	STEP 4b	STEP 5	STEP 6
5	4	4.6 a)	0.870	-0.197 h)	2	-0.197	-0.109 p)	
10	13	4.6			2	0.966 k)		0.966 s)
15	6	4.8 b)	1.250 e)			0.124 l)	0.124	
20	0	4.0	0	-1.000	-		0	
25	1		0.714	-0.340 i)	3	-0.340	-0.188	
30	0	0.4	0	-1.000	-			
35	0	1.0 c)	0 f)		-	-1.000		
40	1		1.000	-0.076		-0.076		
45	3			1.771 j)	2	1.062 m)	1.062	
50	1						-0.127 q)	
55	0		0	-1.000	-	-1.000	0 r)	
60	1	0.4 d)				0.524 n)		
			Σ		SP:			
(Σ/12) = M:			1.083 g)		SN:		ASP:	
				-SP/SN = R:		0.553 o)		

Step 1: Calculate the moving average, MA(L) over 5 neighbours.

Examples: (see Fig. A and worksheet table)

MA(5) = (0+0+4+13+6)/5 = 4.6 a)
(two zeroes added at start of the sample)
MA(15) = (4+13+6+0+1)/5 = 4.8 b)
MA(35) = (1+0+0+1+3)/5 = 1.0 c)
MA(60) = (1+0+1+0+0)/5 = 0.4 d)

Step 2: Divide the original frequencies, FRQ(L), by the moving average and calculate their mean value, M:

Examples:

6/4.8 = 1.25 e)
0/1 = 0 f)

Σ_L FRQ(L)/MA(L) = 12.993

$\frac{1}{12} \Sigma_L$ FRQ(L)/MA(L) = M = 12.993/12 = 1.083 g)

(12 = number of length intervals)

Step 3: Divide FRQ/MA by M and subtract 1

Examples:

0.870/1.083 - 1 = -0.197 h)
0.714/1.083 - 1 = -0.341 i)
3.000/1.083 - 1 = 1.771 j)

Step 4a: Count numbers of "zero neighbours" among the four neighbours (two zeroes added to each end of the sample)

Step 4b: De-emphasize positive isolated values: For each "zero-neighbour" the isolated point is reduced by 20%:

If FRQ > 0 then replace FRQ by FRQ * [1 - 0.2 * (no. of zeroes)]

Examples:

1.610 * (1 - 0.2 * 2) = 0.966 k)
0.154 * (1 - 0.2 * 1) = 0.130 l)
1.771 * (1 - 0.2 * 2) = 1.062 m)
1.309 * (1 - 0.2 * 3) = 0.524 n)

Note: In the most recent version (Gayanilo, Soriano and Pauly, 1988) the de-emphasizing has been made more pronounced by using the factor:

$\frac{1}{(\text{no. of zeroes})}$ instead of [1 - 0.2 * (no. of zeroes)]

Step 4c: Calculate sum, SP, of positive (restructured) FRQs and calculate sum, SN, of negative (restructured) FRQs and calculate the ratio R = -SP/SN

Example:

SP = 0.966 + 0.124 + 1.062 + 0.524 = 2.676
SN = - 0.197 - 1 - 0.340 - 1 - 1 - 0.076 - 0.230 - 1 = - 4.843
R = - SP/SN = 2.676/4.843 = 0.553 o)

Step 5: If FRQ = -1 then replace FRQ by 0
If FRQ < 0 then replace FRQ by R * FRQ

Examples:

-0.197 * 0.553 = -0.109 p)
-0.231 * 0.533 = -0.123 q)
FRQ(55) = 0 r)

Step 6: Calculate ASP (available sum of peaks). Identify the highest point in each sequence of intervals with positive points (a "sequence" may consist in a single interval)

Examples:

0.966 is the highest point in the positive sequence 10-15 cm s)
1.062 is the highest point in the positive sequence 45-45 cm
0.524 is the highest point in the positive sequence 60-60 cm

ASP = 0.966 + 1.062 + 0.524 = 2.552

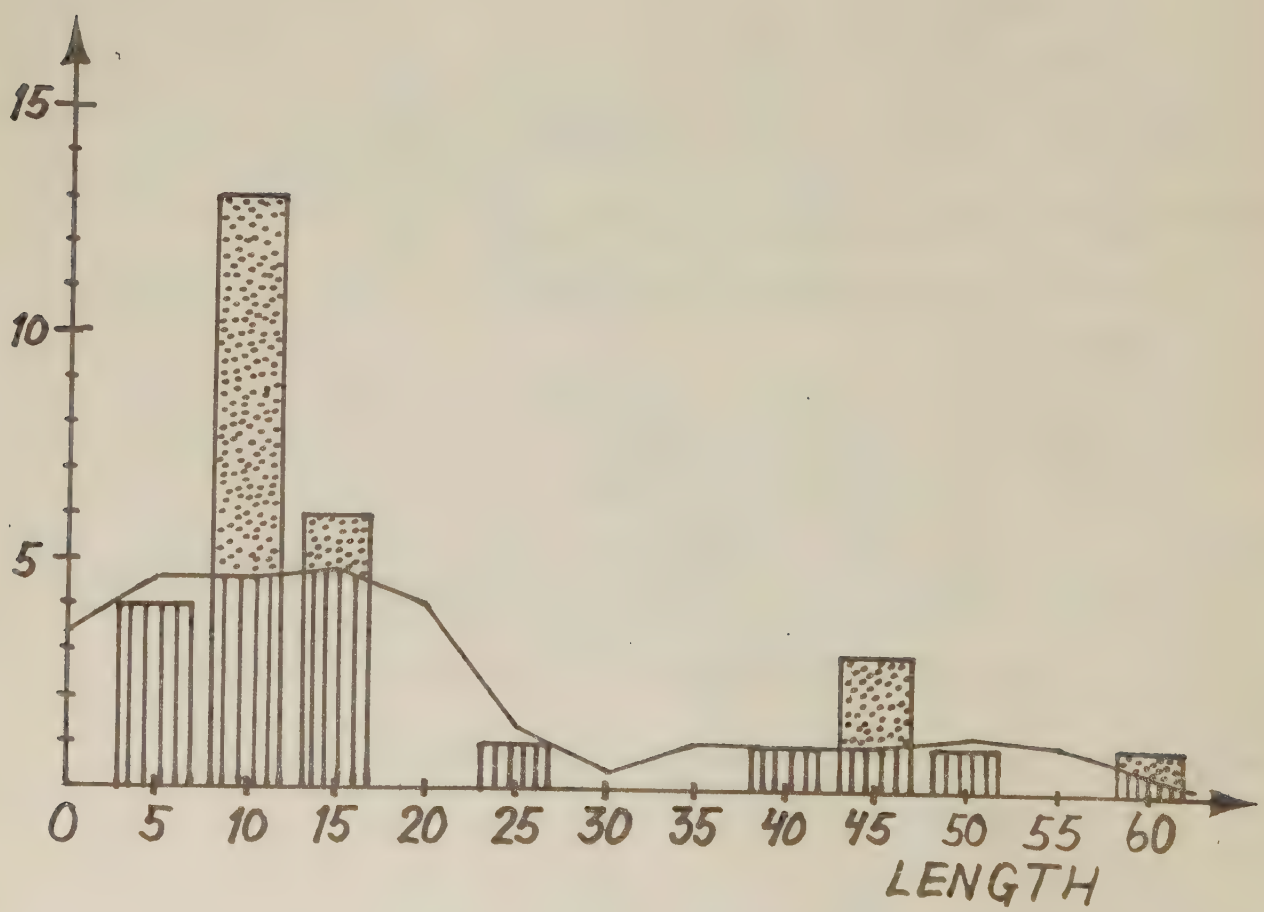


Fig. 17.3.5.1A

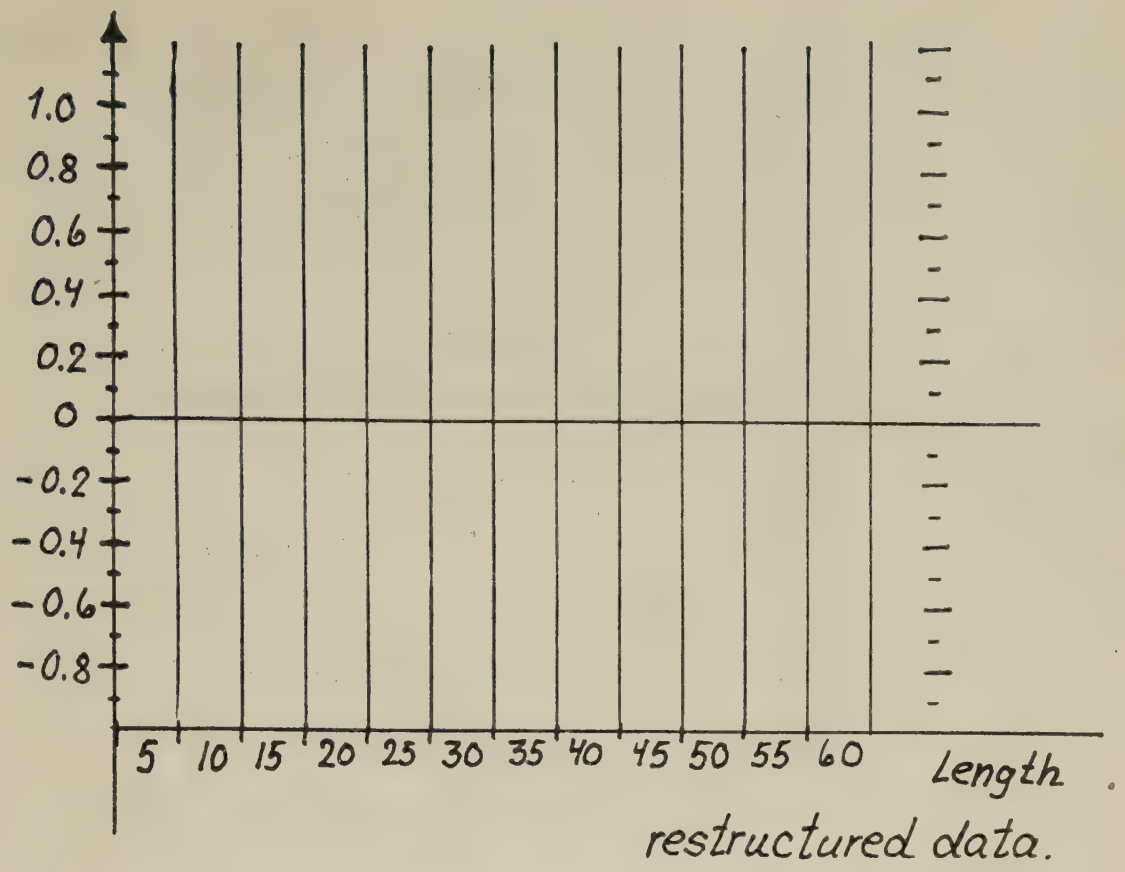


Fig. 17.3.5.1B

Exercise 3.5.1a ELEFAN I, continued

This exercise aims at illustrating the importance of the choice of the size of the length interval (cf. Exercise 3.4.1).

Fig. 17.3.5.1C.1 shows a length frequency sample (from Macdonald and Pitcher, 1979) of 523 pike from Heming Lake, Canada, grouped in 2 cm length intervals. There are five cohorts, determined on the basis of age reading of scales with the mean lengths shown in the following table:

age	mean length	std. dev.
1	23.3	2.44
2	33.1	3.00
3	41.3	4.27
4	51.2	5.08
5	61.3	7.07

These data put us in a position to test ELEFAN I.

Fig. 17.3.5.1C.2 shows the normally distributed components derived from scale readings, and Fig. C.3 shows the restructured data.

Except for the largest fish ELEFAN I manages to place the ASPs (indicated by arrows) close to where the "true" mean lengths of the cohorts are, but like all other methods ELEFAN I has difficulties in handling the largest (oldest) fish.

Tasks:

Repeat the restructuring using the worksheet (3.5.1a) on the basis of 4 cm intervals (see worksheet figure) instead of 2 cm intervals.

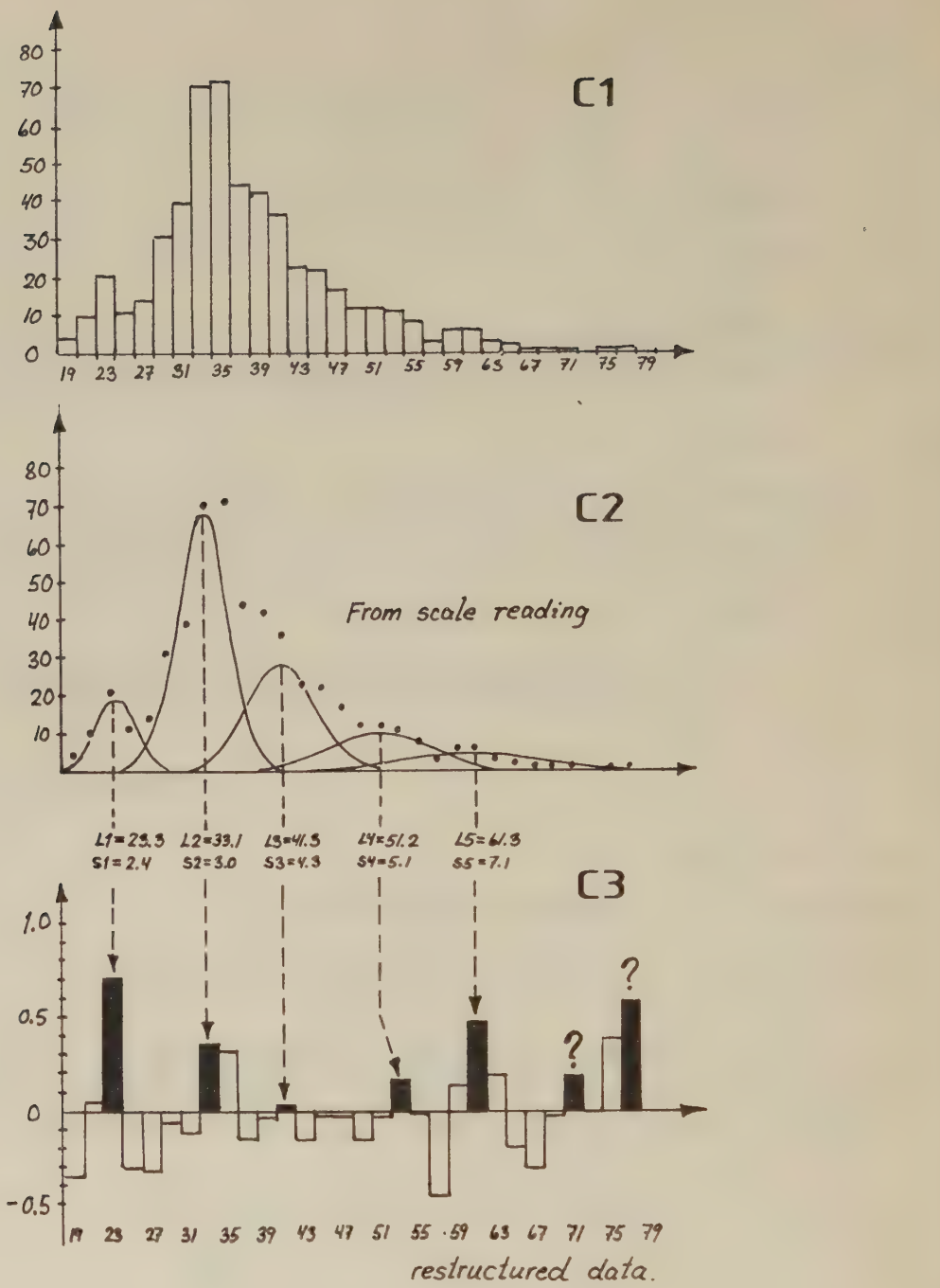


Fig. 17.3.5.1C

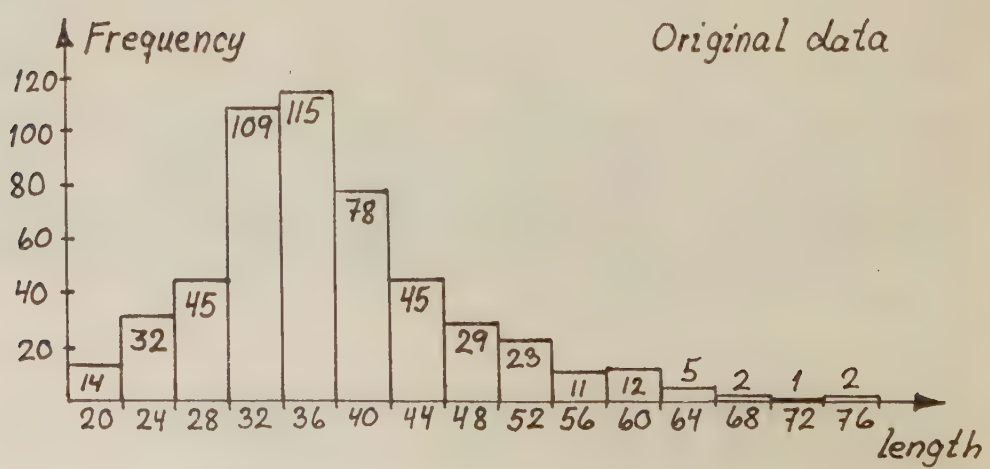


Fig. 17.3.5.1D

Worksheet 3.5.1a

RESTRUCTURING OF LENGTH FREQUENCY SAMPLE

mid-lgt. L	orig. freq. FRQ(L)	STEP 1 MA(L)	STEP 2 FRQ/MA	STEP 3 FRQ/MA/M-1	STEP 4a	STEP 4b	STEP 5	STEP 6
20	14							
24	32							
28	45							
32	109							
36	115							
40	78							
44	45							
48	29							
52	23							
56	11							
60	12							
64	5							
68	2							
72	1							
76	2							
		Σ			SP:			
	(Σ/15) = M:				SN:		ASP:	
				-SP/SN = R:				

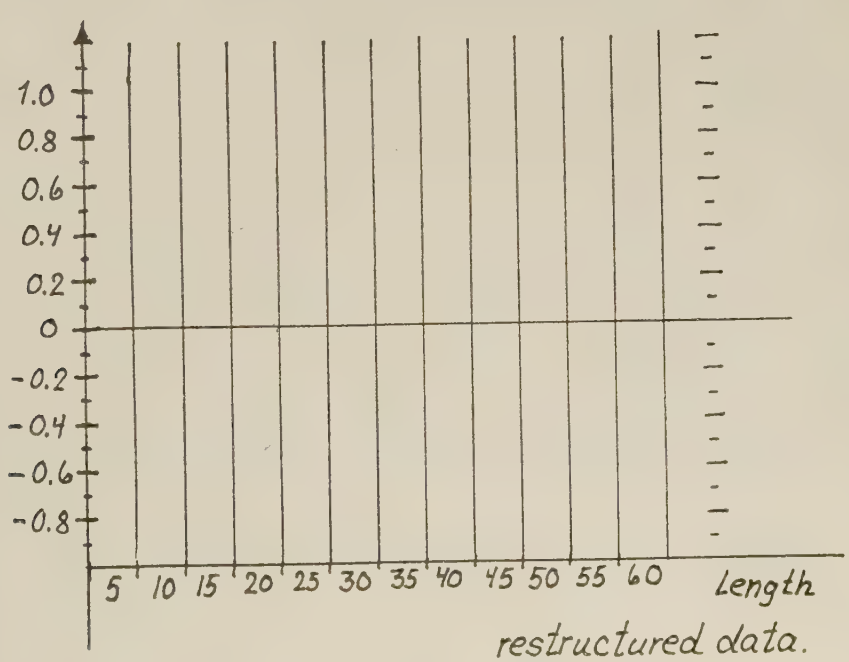


Fig. 17.3.5.1E restructured data.

Exercise 4.2 **The dynamics of a cohort (exponential decay model with variable Z)**

Consider a cohort of a demersal fish species recruiting to the bottom stage at an age t, which is arbitrarily put to zero. Recruitment to the bottom stage is N(0) = 10000.

Tasks:

1) Calculate, using the worksheet, for the first ten half year periods the number of survivors at the beginning of each period and the numbers caught when mortality rates are as shown below:

age (years) t	natural mortality M	fishing mortality F	Comments
0.0-0.5	2.0	0.0	Cohort still on the nursery ground
0.5-1.0	1.5.	0.0	Exposed to heavy predation due to small size
1.0-1.5	0.5	0.2	Cohort under migration to fishing
1.5-2.0	0.3	0.4	ground. Some fish escape through meshes
2.0-2.5	0.3	0.6	
2.5-3.0	0.3	0.6	Cohort under full exploitation
3.0-3.5	0.3	0.6	
3.5-4.0	0.3	0.6	Predation pressure reduced
4.0-4.5	0.3	0.6	
4.5-5.0	0.3	0.6	

Recruitment to the bottom stage: N(0) = 10000

2) Give a graphical presentation of the results.

Worksheet 4.2

t	M	F	Z	$e^{-0.5Z}$	N(t)	N(t) - N(t + 0.5)	F/Z	C
0.0-0.5	2.0	0.0						
0.5-1.0	1.5	0.0						
1.0-1.5	0.5	0.2						
1.5-2.0	0.3	0.4						
2.0-2.5	0.3	0.6						
2.5-3.0	0.3	0.6						
3.0-3.5	0.3	0.6						
3.5-4.0	0.3	0.6						
4.0-4.5	0.3	0.6						
4.5-5.0	0.3	0.6						

Exercise 4.2a **The dynamics of a cohort (the formula for average number of survivors, Eq. 4.2.9)**

Tasks:

Calculate the average number of survivors during the last 3 years for the cohort dealt with in Exercise 4.2.1 using the exact expression (Eq. 4.2.9) and the approximation demonstrated in Fig. 4.2.3, i.e. calculate N(2.0,5.0).

Exercise 4.3 **Estimation of Z from CPUE data**

Assume that the data in Table 3.2.1.2 are numbers caught per hour trawling.

Tasks:

Estimate the total mortality for the stock under the assumption of constant recruitment, using Eq. 4.3.0.3:

$$Z = \frac{1}{t2-t1} \ln \frac{CPUE(t1)}{CPUE(t2)}$$

Worksheet 4.3

	cohort	1982 A	1982 S	1981 A	1981 S	1980 A
	age t2	1.16				
	CPUE	111	67	40		
co-hort	age t1	CPUE				
83 S	0.64	182				
82 A	1.16	111	——			
82 S		67	——	——		
81 A	2.10		——	——	——	
81 S	2.64	24	——	——	——	——

Exercise 4.4.3 **The linearized catch curve based on age composition data**

Use the data presented in Table 4.4.3.1.

Tasks:

Estimate Z from the catches of the 1974-cohort after plotting the catch curve. Calculate the confidence limits of the estimate of Z.

Worksheet 4.4.3

age t	year y	C(y,t,t+1)	ln C(y,t,t+1)	Remarks
0				
1				
2				
3				
4				
5				
6				
7	1981	-	-	

slope: b = $sb^2 = [(sy/sx)^2 - b^2]/(n-2)$ =

sb = sb t(n-2) = Z = ±

Exercise 4.4.5 **The linearized catch curve based on length composition data**

Length-frequency data from Ziegler (1979) for the threadfin bream (Nemipterus japonicus) from Manila Bay are given in the worksheet below, L_∞ = 29.2 cm, K = 0.607 per year.

Tasks:

1) Carry out the length converted catch curve analysis, using the worksheet.

2) Draw the catch curve.

3) Calculate the confidence limits for each estimate of Z.

Worksheet 4.4.5

a) Length converted catch curve analysis

L1-L2	C(L1,L2)	t(L1)	Δt	$t(\frac{L1+L2}{2})$	$\ln \frac{C(L1,L2)}{\Delta t}$	Z	remarks
7 -8	11						not used, not under full exploitation
8 -9	69						
9-10	187						
10-11	133						?
11-12	114						?
12-13	261						?
13-14	386						?
14-15	445						?
15-16	535						?
16-17	407						?
17-18	428						?
18-19	338						?
19-20	184						?
20-21	73						?
21-22	37						?
22-23	21						?
23-24	19						?
24-25	8						?
25-26	7						?
26-27	2						too close to L_∞

b) Details of the regression analyses:

L1-L2	Z	number of obs. n	Students distrib. t(n-2)	variance of slope sb^2	confidence limits Z ± t(n-2) sb

Exercise 4.4.6 **The cumulated catch curve based on length composition data (the Jones and van Zalinge method)**

Length-frequency data from Ziegler (1979) for the threadfin bream (Nemipterus japonicus) from Manila Bay are given in the worksheet below, L_∞ = 29.2 cm, K = 0.607 per year.

Tasks:

1) Determine Z/K by the Jones and van Zalinge method, using the worksheet.

2) Plot the "catch curve".

3) Calculate the 95% confidence limits for each estimate of Z (worksheet).

Worksheet 4.4.6

Jones and van Zalinge method

L1-L2	C(L1,L2)	cumulated $C(L1,L_\infty)$	ln $C(L1,L_\infty)$	$\ln(L_\infty - L1)$	slope Z/K	remarks
7- 8	11					not used, not under full exploitation
8- 9	69					
9-10	187					
10-11	133					?
11-12	114					?
12-13	261					?
13-14	386					?
14-15	445					?
15-16	535					?
16-17	407					?
17-18	428					?
18-19	338					?
19-20	184					?
20-21	73					?
21-22	37					?
22-23	21					?
23-24	19					?
24-25	8					?
25-26	7					?
26-27	2					too close to L_∞

Details of the regression analyses

L1-L2	Z	number of obs. n	Students distrib. t(n-2)	variance of slope sb^2	confidence limits Z ± t(n-2) sb

Exercise 4.4.6a The Jones and van Zalinge method applied to shrimp

Carapace length-frequency data for female shrimp (Penaeus semisulcatus) from Kuwait waters, 1974-1975, from Jones and van Zalinge (1981), are presented in the worksheet below. L_∞ = 47.5 mm (carapace length). Input data are total landings in millions of shrimps per year by the Kuwait industrial shrimp fishery.

Note: In this case the length intervals have different sizes, because the length groups have been derived from commercial size groups, which are given in the number of tails per pound (1 kg = 2.2 pounds).

Tasks:

1) Determine Z/K by the Jones and van Zalinge method.
2) Plot the "catch curve".
3) Calculate the 95% confidence limits for each estimate of Z/K.

Worksheet 4.4.6a

Jones and van Zalinge method for shrimps

carapace length mm L1	numbers landed/yr (millions) C(L1,L2)	cumulated numbers/yr (millions) $C(L1,L_\infty)$	$\ln C(L1,L_\infty)$	$\ln(L_\infty - L1)$	Z/K	remarks
11.18	2.81					
18.55	1.30					
22.15	2.96					
25.27	3.18					
27.58	2.00					
29.06	1.89					
30.87	1.78					
33.16	0.98					
36.19	0.63					
40.50	0.63					

Details of the regression analyses:

L1	n	t(n-2)	sb^2	Z/K ± t(n-2)sb

Exercise 4.5.1 **Beverton and Holt's Z-equation based on length data (applied to shrimp)**

The same data as for Exercise 4.4.6a (from Jones and van Zalinge, 1981) on Penaeus semisulcatus are given in the worksheet below. L_∞ = 47.5 mm (carapace length).

Tasks:

Estimate Z/K using Beverton and Holt's Z-equation (Eq. 4.5.1) and the worksheet.

Worksheet 4.5.1

carapace length mm L1 = L'	numbers landed/yr (millions) C(L1,L2)	mid-length $\frac{L1+L2}{2}$	C $\frac{L1+L2}{2}$	ΣC	Σ C $\frac{L1+L2}{2}$	$\bar{L}$	Z/K	remarks
11.18	2.81							
18.55	1.30							
22.15	2.96							
25.27	3.18							
27.58	2.00							
29.06	1.89							
30.87	1.78							
33.16	0.98							
36.19	0.63							
40.50	0.63							
47.50								

Exercise 4.6 **Plot of Z on effort (estimation of M and q)**

For the trawl fishery in the Gulf of Thailand the effort (in millions of trawling hours and the mean length of the bulls eye (Priacanthus tayenus) over the years 1966-1974 were taken from Boonyubol and Hongskul (1978) and South China Sea Fisheries Development Programme (1978) and presented in the worksheet below (L_∞ = 29.0 cm, K = 1.2 per year, Lc = 7.6 cm).

Tasks:

1) Calculate Z, using the worksheet.
2) Plot Z against effort and determine M (intercept) and q (slope).
3) Calculate the 95% confidence limits for the estimates of M and q.

Use the following two sets of input data (years):

a) The years 1966-1970
b) The years 1966-1974

and comment on the results.

Worksheet 4.6

year	effort a)	mean length $\overline{Lc}$	$Z = K \frac{L\infty - \overline{Lc}}{\overline{Lc} - Lc}$ (Eq. 4.5.3)
1966	2.08	15.7	1.97
1967	2.80	15.5	
1968	3.50	16.1	
1969	3.60	14.9	
1970	3.80	14.4	
1971	-	no data -	-
1972	-	no data -	-
1973	9.94	12.8	
1974	6.06	12.8	

a) in millions of trawling hours

Exercise 5.2 **Age based cohort analysis (Pope's cohort analysis)**

Catch data by age group of the North Sea whiting (from ICES, 1981) are presented in Tables 5.1.1 and 4.4.3.1.

Tasks:

1) Calculate fishing mortalities for the 1974 cohort (catch numbers given in Table 5.1.1 and M = 0.2 per year) by Pope's cohort analysis under the two different assumptions on the F for the oldest age group:

   F6 = 1.0 per year
   F6 = 2.0 per year

2) Plot F against age for the two cases above as well as for the case of Table 5.1.1, where

   F6 = 0.5 per year

3) Discuss the significance of the choice of the terminal F (F6). Which of the three alternatives do you prefer? (Base your decision on the solution to Exercise 4.4.3, which deals with the same data set).

Exercise 5.3 A predictive age based model (Thompson and Bell analysis)

In the (hypothetical example) given in the table below a fish stock is exploited by two different gears, viz. beach seines and gill nets. These gears account for the total catch from the stock. A sampling programme for estimation of total numbers caught by age group and by gear has been running for the years 1975-1985.

Based on the total numbers caught a VPA has been made and the estimated F values for the last data year (1985) have been separated into a beach seine component, FB and a gill net component FG (cf. Eq. 5.3.1). The average recruitment (number of 0-group fish) for the years 1975 to 1985 has been estimated from VPA to be 1000000 fish. The natural mortalities are assumed to take the age-specific values. These data are presented in part a of the worksheet.

Tasks:

Use worksheet 5.3a to solve the following problems:

1) Under the assumption that fishing mortality remains the same in 1986 as in 1985 and that the recruitment in 1986 is of average size, predict for 1986:

   1.1) The number of survivors (stock numbers) by age group.
   1.2) Numbers caught by age group for each gear.
   1.3) Yield of each gear.

Use worksheet 5.3b.

2) Under the assumption that the gill net effort remains the same in 1986 as in 1985 but that the beach seine fishery is closed (and that the recruitment in 1986 is of average size) predict for 1986 as for part 1 above.

3) Would it not be necessary to continue the analysis through several years assuming no further changes in F?

4) Would you, based on the results of 1) and 2) recommend a closure of the beach seine fishery?

Worksheet 5.3

a. No change in fishing effort from 1985 to 1986:

age gr. t	mean wgt. (g) W	beach seine FB	gill net FG	nat. mort. M	tot. mort. Z	stock num-ber N	beach seine catch CB	gill net catch CG	beach seine yield YB	gill net yield YG	total yield YB+YG
0	8	0.05	0.00	2.00		1000					
1	283	0.40	0.00	0.80							
2	1155	0.10	0.14	0.30							
3	2406	0.01	0.59	0.20							
4	3764	0.00	0.38	0.20							
5	5046	0.00	0.09	0.20							
6	6164	0.00	0.02	0.20							
7	7090	0.00	0.00	0.20							
					Total						

$Z = FB + FG + M$ $\qquad N(t+1) = N(t)\ \exp(-Z)$

$CB = FB * N * (1-\exp(-Z))/Z$ $\qquad CG = FG * N * (1-\exp(-Z))/Z$

$YB = CB * W$ $\qquad YG = CG * W$

b. Closure of the beach seine fishery:

age gr. t	mean wgt. (g) W	beach seine FB	gill net FG	nat. mort. M	tot. mort. Z	stock num-ber N	beach seine catch CB	gill net catch CG	beach seine yield YB	gill net yield YG	total yield YB+YG
0	8										
1	283										
2	1155										
3	2406										
4	3764										
5	5046										
6	6164										
7	7090										
					Total						

Exercise 5.4 **Jones' length based cohort analysis**

As in exercises 4.4.6a and 4.5.1 we use the landings of female Penaeus semisulcatus of the 74/75-cohort from Kuwait waters (from Jones and van Zalinge, 1981). These data were derived from the total number of processed prawns in each of ten market categories (cf. worksheet 5.4).

Tasks:

1) Estimate fishing mortalities and stock numbers by means of Jones' length cohort analysis, using the parameters:

   K = 2.6 per year
   M = 3.9 per year
   L_∞ = 47.5 mm (carapace length)

2) Give your opinion on our choice of terminal F/Z (= 0.1).

3) Is the cohort analysis a dependable method in this case? (The value of M is a "guesstimate").

Worksheet 5.4

lower limit length group g) L1	a) X(L1,L2)	number caught (mill.) C(L1,L2)	number of survivors b) N(L1)	exploitation rate c) F/Z	fishing mort. d) F	total mort. e) Z
11.18		2.81				
18.55		1.30				
22.15		2.96				
25.27		3.18				
27.58		2.00				
29.06		1.89				
30.87		1.78				
33.16		0.98				
36.19		0.63				
40.50		0.63	f)	0.1		

a) $X(L1,L2) = \left[\frac{L\infty - L1}{L\infty - L2} \right]^{M/2K}$

b) $N(L1) = [N(L2)\ X(L1,L2) + C(L1,L2)]\ X(L1,L2)$
c) $F/Z = C(L1,L2)/[N(L1)-N(L2)]$
d) $F = M\ (F/Z)/(1 - F/Z)$
e) $Z = F + M$
f) $N(\text{last L1}) = C(\text{last L1}, L_\infty)/(F/Z)$
g) carapace length in mm corresponding to the market categories (in units of number of tails per lb):

no/lb:	400	110	70	50	40	35	30	25	20	<15
L1 :	11.18	18.55	22.15	25.27	27.58	29.06	30.87	33.16	36.19	40.5

Exercise 5.5 **A predictive length based model (Thompson and Bell analysis)**

For this exercise a hypothetical example is used:

M = 0.3 per year, K = 0.3 per year, L_∞ = 60.0 cm

q in $W = qL^b$: 0.01 g/cm^3, b in $W = qL^b$: 3.0
Recruitment, N(10,15) = 1000

length class L1-L2	fishing mortality F(L1,L2) b)	body weight g W(L1.L2)	price per kg	X a) X(L1,L2)
10-15	0.03	19.5	1.0	1.05409
15-20	0.20	53.6	1.0	1.06066
20-25	0.40	113.9	1.5	1.06904
25-30	0.70	207.9	1.5	1.08012
30-35	0.70	343.3	2.0	1.09544
35-40	0.70	527.3	2.0	1.11803
40-L_∞	0.70	767.7	2.0	-

a) $X = ((L_\infty - Li)/(L_\infty - Li+1))^{M/2K}$
b) F-values used in Exercise 5.5

Tasks:

Do the length converted Thompson and Bell analysis on the example.

Worksheet 5.5

length L1-L2	F(L1,L2)	N(L1) a)	mean biomass b)	catch C(L1,L2) c)	YIELD(L1,L2) d)	VALUE e)
10-15	0.03	1000				
15-20	0.20					
20-25	0.40					
25-30	0.70					
30-35	0.70					
35-40	0.70					
40-L_∞	0.70		f)			
	Total	———				

a) N(L2) = N(L1) * (1/X(L1,L2)-E(L1,L2))/(X(L1,L2)-E(L1,L2))
where E(L1,L2) = F(L1,L2)/Z(L1,L2)

b) NMEAN(L1,L2) = (N(L1)-N(L2))/Z(L1,L2), mean number
Mean biomass = NMEAN(L1,L2) * W(L1,L2)

c) C(L1,L2) = F(L1,L2) * NMEAN(L1,L2)
d) YIELD(L1,L2) = C(L1,L2) * W(L1,L2)
e) VALUE(L1,L2) = YIELD(L1,L2) * PRICE(L1,L2)
f) Mean biomass = N(40) * $W(40,L_\infty)/Z(40,L_\infty)$

Exercise 5.5a **A predictive length based model (Yield curve, Thompson and Bell analysis)**

Tasks:

1) Do the same exercise as in Exercise 5.5 but under the assumption of a 100% increase in fishing effort.

2) Use the result of 1) combined with the solution to Exercise 5.5 and the results given in the table below to draw the yield and the value curves.

X	Yield	Mean Biomass	Value
0.0	0.00	1445.41	0.00
0.2	116.38	865.89	226.11
0.4	154.48	585.63	296.49
0.6	165.12	426.42	312.70
0.8	164.75	326.87	307.56
1.0			
1.2	153.25	213.94	277.35
1.4	146.23	180.15	260.38
1.6	139.37	154.84	244.14
1.8	132.95	135.40	229.10
2.0			

MSY = 165.8 X = .69 Biom.msy = 378.8
MSE = 312.9 X = .61 Biom.mse = 405.7

(These values were calculated by the "MIXFISH" program of the LFSA package).

Worksheet 5.5a

Length L1-L2	F(L1,L2)	N(L1) a)	Mean Biomass b)	Catch C(L1,L2) c)	YIELD(L1,L2) d)	VALUE e)
10-15		1000.00				
15-20						
20-25						
25-30						
30-35						
35-40						
40-L_∞			f)			
Total						

a) $N(L2) = N(L1) * (1/X(L1,12)-E(L1,L2))/(X(L1,L2)-E(L1,L2))$
where $E(L1,L2) = F(L1,L2)/Z(L1,L2)$

b) $NMEAN(L1,L2) = (N(L1)-N(12))/Z(L1,L2)$
Mean Biomass = $NMEAN(L1,L2) * W(L1,L2)$

c) $C(L1,L2) = F(L1,L2) * NMEAN(L1,L2)$
d) $YIELD(L1,L2) = C(L1,L2) * W(L1,L2)$
e) $VALUE(L1,L2) = YIELD(L1,L2) * PRICE(L1,L2)$
f) Mean biomass = $N(40) * W(40,L_\infty)/Z(40,L_\infty)$

Exercise 6.1.1 **A mathematical model for the selection ogive**

Tasks:

Draw a selection curve using the parameters:

L50% = 13.6 cm and L75% = 14.6 cm

Use the logistic curve S(L) = 1/(1+exp(S1-S2 * L))

Exercise 6.1.2 Estimation of the selection ogive from a catch curve

Date on catch by length group of Upeneus vittatus were taken from Table 4.4.5.1.

Tasks:

1) Estimate L50% and L75%.

2) Evaluate the choice of first length interval given in Table 4.4.5.1.

Worksheet 6.1.2

A	B	C	D	E	F	G	H
L1-L2 length group	t a) X	/\t	C(L1,L2)	b)	S c)	d) Y	S e)
6- 7	0.56	0.102	3	3.38			(not used)
7- 8	0.67	0.109	143	7.18			
8- 9	0.78	0.116	271	7.76			
9-10	0.90	0.125	318	7.86			
10-11	1.03	0.134	416	8.04			
11-12	1.17	0.146	488	8.11			
12-13	1.32	0.160	614	8.25			
13-14	1.49	0.177	613	f) 8.15			
14-15	1.67	0.197	493	f) 7.83			
15-16	1.88	0.223	278	f) 7.13			
16-17	2.12	0.257	93	f) 5.89			
17-18	2.40	0.303	73	f) 5.48			
18-19	2.74	0.370	7	f) 2.94			
19-20	3.15	0.473	2	f) 1.44			
20-21	3.70	0.659	2	1.11			
21-22	4.53	1.094	0	-			
22-23	6.19	4.094	1	-1.40			
23-24	-	-	1	-			

a) t[(L1+L2)/2], age corresponding to interval midlength
b) ln(C/\t), dependent variable in catch curve regression analysis
c) S = C/[\t * exp(a-Z * t)], observed selection ogive
   Z = 4.19 and a = 14.8 (from Table 4.4.5.1)
d) ln(1/S - 1), dependent variable in regression
e) 1/[1 + exp(T1-T2 * t)], theoretical (estimated) selection ogive
f) Points used in the catch curve analysis (cf. Table 4.4.5.1)
   K = 0.59 per year, L_∞ = 23.1 cm, t_o = -0.1 year

Exercise 6.5 **Using a selection curve to adjust catch samples**

Tasks:

1) Adjust the length frequencies for Upeneus vittatus (from the data given in Table 4.4.5.1) using the results of Exercise 6.1.2:

   L50% = 13.6 cm and L75% = 14.6 cm

2) Draw a histogram of the original and the adjusted frequencies excluding the raised (estimated unbiased) frequencies which you think are not safely estimated.

Worksheet 6.5

length group	observed biased sample	selection ogive S	estimated unbiased sample
6- 7	3		
7- 8	143		
8- 9	271		
9-10	318		
10-11	416		
11-12	488		
12-13	614		
13-14	613		
14-15	493		
15-16	278		
16-17	93		
17-18	73		
18-19	7		
19-20	2		
20-21	2		
21-22	0		
22-23	1		
23-24	1		

Exercise 8.3 **The yield per recruit model of Beverton and Holt (Yield per recruit, biomass per recruit as a function of F)**

Pauly (1980) determined the following parameters for Leiognathus splendens (cf. Exercise 3.3.6). W_∞ = 64 g, K = 1.0 per year, t_o = -0.2 year, Tr = 0.2 year, M = 1.8 per year.

Tasks:

1) Draw the Y/R-curve and the B/R-curve. Use three different values of Tc: Tc = Tr, Tc = 0.3 year and Tc = 1.0 year.

Worksheet 8.3

	Tc = Tr		Tc = 0.3		Tc = 1.0	
F	Y/R	B/R	Y/R	B/R	Y/R	B/R
0.0						
0.2						
0.4						
0.6						
0.8						
1.0						
1.2						
1.4						
1.6						
1.8						
2.0						
2.2						
2.4						
2.6						
2.8						
3.0						
3.5						
4.0						
4.5						
5.0						
100.0						

2) Try to explain why MSY increases when Tc increases (without the use of mathematics). Is the above statement a general rule, i.e. does it hold for any increase of Tc?

3) Read the (approximate) values of F(MSY) and MSY/R from the worksheet. Comment on your findings under the assumption that the present level of F is 1.0.

Exercise 8.4 Beverton and Holt's relative yield per recruit concept

For the swordfish (Xiphias gladius) off Florida, Berkeley and Houde (1980) determined the parameters:

L_∞ = 309 cm, K = 0.0949 per year and M = 0.18 per year

Tasks:

Draw the relative yield per recruit curve, (Y/R') as a function of E, for two different values of the 50% retention length:

Lc = 118 cm and Lc = 150 cm.

Worksheet 8.4

E	Lc = 118 cm (Y/R)'	Lc =150 cm (Y/R)'	(F)
0			0
0.1			0.020
0.2			0.045
0.3			0.077
0.4			0.120
0.5			M = 0.180
0.6			0.270
0.7			0.42
0.8			0.72
0.9			1.62
1.0			∞

Exercise 9.1 The Schaefer model and the Fox model

In Worksheet 9.1 are given total catch and total effort in standard boat days for the years 1969 through 1978 for the shrimp fishery in the Arafura Sea. Catches are mainly composed of the five species Penaeus merguiensis, Penaeus semisulcatus, Penaeus monodon, Metapenaeus ensis and Parapenaeopsis sculptilis (from Naamin and Noer, 1980).

Tasks:

1) Calculate Y/f (kg per boat day) and ln(Y/f) and plot them on effort.
2) Estimate MSY and F(MSY) by the Schaefer model.
3) Estimate MSY and F(MSY) by the Fox model.
4) Plot yield on effort and draw the yield curves estimated by the two methods.

Worksheet 9.1

year i	yield (tons headless) Y(i)	effort f(i) *) x	SCHAEFER Y/f **) y	FOX ln(Y/f) y
1969	546.7	1224		
1970	812.4	2202		
1971	2493.3	6684		
1972	4358.6	12418		
1973	6891.5	16019		
1974	6532.0	21552		
1975	4737.1	24570		
1976	5567.4	29441		
1977	5687.7	28575		
1978	5984.0	30172		
mean value:				
standard deviation:				
intercept (Schaefer: a, Fox: c):				
slope (Schaefer: b, Fox: d):				

*) in boat days, **) kg per boat day

continuation of Worksheet 9.1

variance of slope:
$sb^2 = [(sy/sx)^2 - b^2]/(10-2)$ ***):

standard deviation of slope, sb ***):
confidence limits of slope:
b + t(n-2) sb upper:
lower:

variance of intercept:

$sa^2 = sb^2 (sx^2 (n-1)/n + x^2)$ ***):

standard deviation of intercept:
confidence limits of intercept :
a + t(n-2) sa iii) upper:
lower:

MSY: Schaefer: $-a^2/(4b)$:
Fox : $-(1/d) \exp(c-1)$:

F(MSY): Schaefer: - a/(2b):
Fox : - 1/d:

***) a,b replaced by c,d for the Fox-model.

Worksheet 9.1a (for drawing the yield curves)

f	Schaefer yield (tons)	Fox yield (tons)
5000		
10000		
15000		
20000		
25000		
F(MSY)		
30000		
35000		
F(MSY)		
40000		
45000		

Exercise 13.8 **The swept area method, precision of the estimate of biomass, estimation of MSY and optimal allocation of hauls**

The data for this exercise were taken from report no. 8 of PROJECT KEN/74/023: "Offshore trawling survey", which deals with the stock assessment of Kenyan demersal resources from surveys in the period 1979-81. The data used here are a modified set on the catch of the small-spotted grunt, Pomadasys opercularis. The data are given as catch per hour trawling for 23 hauls covering two strata in Worksheet 13.8. The vessel speed, current speed and trawl wing spread (h * X2) are also given.

Tasks:

1) Apply Eq. 13.5.3 to calculate the distance, D, covered per hour and Eq. 13.5.1 to calculate the area swept per hour for each haul. Calculate the yield per unit of area for each haul using Eq. 13.6.2 (data in the worksheet, 1 nm = 1852 m).

2) Calculate for each stratum the estimate of mean catch per unit area and the confidence limits of the estimates (using Eq. 2.3.1). Calculate using Eqs. 13.7.5 and 13.6.3 an estimate of the mean biomass for the total area, when A1 = 24 sq. nm. and A2 = 53 sq. nm and X1 is assigned the value 0.5.

3) Estimate MSY using Gulland's formula, with M = Z = 0.6 per year (i.e. we assume a virgin stock).

4) Construct a graph showing the maximum relative error for the mean catch per area against the number of hauls for each of the two strata. We define (cf. Section 2.7, Fig. 2.7.1)

$$\epsilon = (\text{max.rel. error}) = \frac{s * t(n-1)}{\overline{Ca} * \sqrt{n}}$$

where s is the standard deviation of the estimate of the catch in weight per unit area:

$$s = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (Ca(i) - \overline{Ca})^2}$$

5) Assume that you have financial resources to make 200 hauls. Allocate these 200 hauls between the two strata for optimum stratified sampling (cf. Section 2.8).

Worksheet 13.8

STRATUM I:

	A	B	C	D	E	F			
		VESSEL		TRAWL	CURRENT				
haul no. i	Cw/t kg/h	speed knots VS	course deg. dirV	w.spr. m h * x2	speed knots CS	dir. deg. dirC	dist. nm. D	area swept a	Cw/a(Ca) kg/sq.nm.
1	7.0	2.8	220	18	0.5	90			
2	7.0	3.0	210	16	0.5	180			
3	5.0	3.0	200	17	0.3	135			
4	4.0	3.0	180	18	0.4	230			
5	1.0	3.0	90	17	0.5	270			
6	4.0	3.0	45	18	0.4	160			
7	9.0	3.5	25	18	0.4	200			
8	0.0	3.0	210	18	0.3	300			
9	0.0	3.5	0	18	0.4	0			
10	14.0	2.8	45	18	0.6	0			
11	8.0	3.0	120	18	0.3	300			

STRATUM II:

	A	B	C	D	E	F			
		VESSEL		TRAWL	CURRENT				
haul no. i	Cw/t kg/h	speed knots VS	course deg. dirV	w.spr. m h * x2	speed knots CS	dir. deg. dirC	dist. nm. D	area swept a	Cw/a(Ca) kg/sq.nm.
12	42.0	4.0	30	17	0.5	160			
13	98.0	3.3	215	17	0.4	90			
14	223.0	3.9	30	17	0.0	0			
15	59.0	3.8	35	17	0.3	180			
16	32.0	3.5	210	17	0.5	270			
17	6.0	2.8	210	17	0.5	330			
18	66.0	3.8	45	17	0.5	30			
19	60.0	4.0	30	18	0.5	180			
20	48.0	4.0	210	18	0.5	180			
21	52.0	3.8	20	18	0.4	180			
22	48.0	4.0	30	18	0.5	190			
23	18.0	3.0	210	18	0.3	190			

Worksheet 13.8 (continued)

stratum	n number of hauls	Ca	s	$s/\sqrt{n}$	t(n-1)	confidence limits for $\overline{Ca}$
I	11				2.23	
II						

Worksheet 13.8a (for plotting graph)

number of hauls n	t(n-1)	stratum I ϵ *)	stratum II ϵ *)
5	2.78		
10	2.26		
20	2.09		
50	2.01		
100	1.98		
200	1.97		

*) $\epsilon = \frac{s * t(n-1)}{\overline{Ca} * \sqrt{n}}$

Worksheet 13.8b (optimum allocation)

stratum	s	A	A * s	A * s/Σ A * s	200 * A * s/Σ A * s
I					
II					
Total					

18 SOLUTIONS TO EXERCISES

Exercise 2.1 Mean value and variance

Worksheet 2.1

j	L(j)-L(j+1)	F(j)	$\bar{L}(j)$	$F(j)\bar{L}(j)$	$\bar{L}(j)-\bar{x}$	$F(j)(\bar{L}(j)-\bar{x})^2$
1	23.0-23.5	1	23.25	23.25	-2.968	8.809
2	23.5-24.0	1	23.75	23.75	-2.468	6.091
3	24.0-24.5	1	24.25	24.25	-1.968	3.873
4	24.5-25.0	2	24.75	49.50	-1.468	4.310
5	25.0-25.5	2	25.25	50.50	-0.968	1.874
6	25.5-26.0	6	25.75	154.50	-0.468	1.314
7	26.0-26.5	5	26.25	131.25	0.032	0.005
8	26.5-27.0	6	26.75	160.50	0.532	1.698
9	27.0-27.5	2	27.25	54.50	1.032	2.130
10	27.5-28.0	2	27.75	55.50	1.532	4.694
11	28.0-28.5	2	28.25	56.50	2.032	8.258
12	28.5-29.0	1	28.75	28.75	2.532	6.441
		31		812.75		49.467

$\bar{x}$ = 26.218 s^2 = 1.6489 s = 1.2841

Exercise 2.2 The normal distribution

$$A = \frac{n\ dL}{s\ \sqrt{2\pi}} = \frac{31 * 0.5}{1.2841 * \sqrt{2*3.1416}} = 4.816$$

$$B = -1/(2s^2) = -\frac{1}{2 * 1.649} = -0.303$$

$\bar{x}$ = 26.22

Worksheet 2.2

x	Lc(x)	x	Lc(x)
22.0	0.02	26.0	4.75
22.5	0.07	26.5	4.70
23.0	0.21	27.0	4.00
23.5	0.51	27.5	2.93
24.0	1.08	28.0	1.84
24.5	1.97	28.5	0.99
25.0	3.07	29.0	0.46
25.5	4.12	29.5	0.18

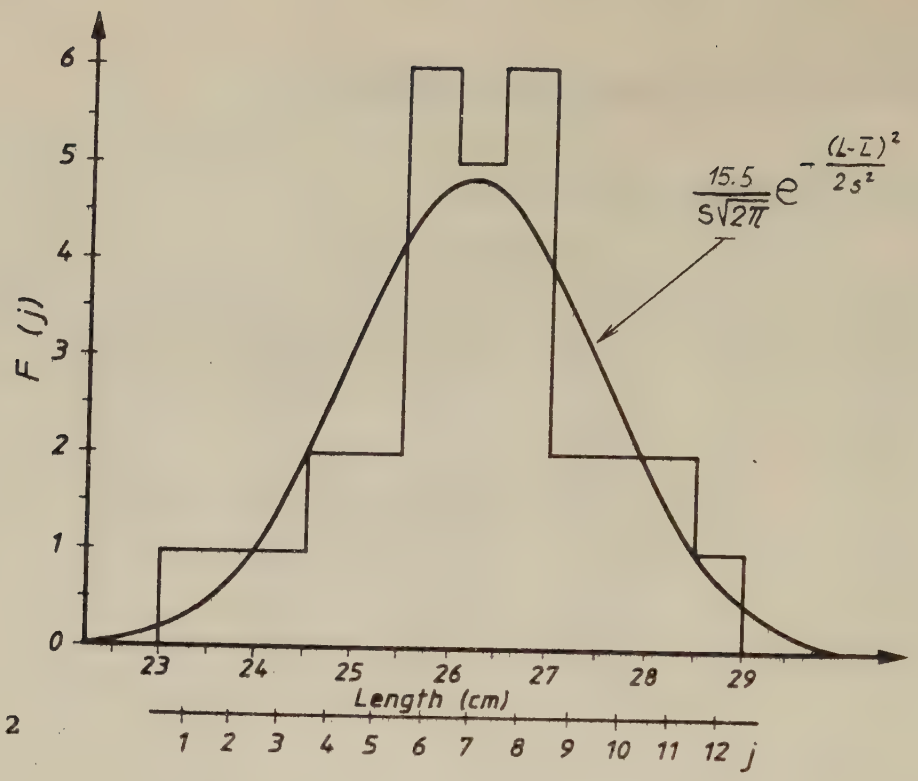


Fig. 18.2.2

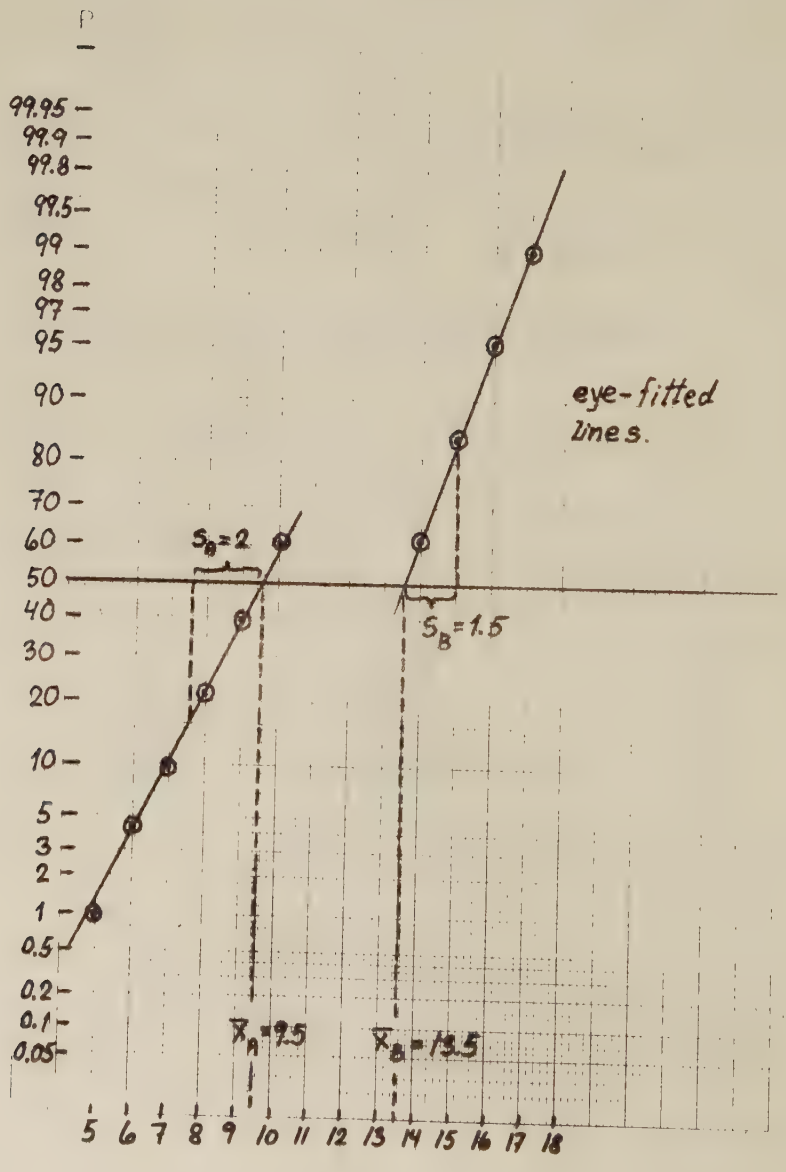


Fig. 18.2.2A

Exercise 2.2a Use of probability paper

Worksheet 2.2a

Interval	F(x-0.5)	F(x-0.5)/199	$\Sigma_{u<x}$ F(u)/199	1 - $\Sigma_{u>x}$ F(u)/199	
4 - 5	2	0.010	0.010	-	
5 - 6	5	0.025	0.035	-	
6 - 7	12	0.060	0.095	-	
7 - 8	24	0.121	0.216	-	clean
8 - 9	35	0.176	0.392	-	
9 -10	42	0.211	0.603	-	
10 -11	42	0.211	0.814	-0.186	conta-
11 -12	46	0.231	(1.045)	0.045	mina-
12 -13	56	0.281	-	0.327	ted-
13 -14	58	0.291	-	0.618	
14 -15	45	0.226	-	0.844	
15 -16	22	0.111	-	0.955	clean
16 -17	7	0.035	-	0.990	
17 -18	2	0.010	-	1.000	

See Fig. 18.2.2a	first component (a)	second component (b)
$\bar{x}$	9.5	13.5
s	2.0	1.5

Lc(x) for component a:

$$\frac{199 * 1}{2.0 * \sqrt{2 * 3.1416}} \exp\ [- (x-9.5)^2/(2 * 2.0)] = 39.5 \exp\left[- \frac{(x-9.5)^2}{8} \right]$$

Lc(x) for component b:

$$\frac{199 * 1}{1.5 * \sqrt{2 * 3.1416}} \exp\ [- (x-13.5)^2/(2 * 1.5)] = 52.9 \exp\left[- \frac{(x-9.5)^2}{4.5} \right]$$

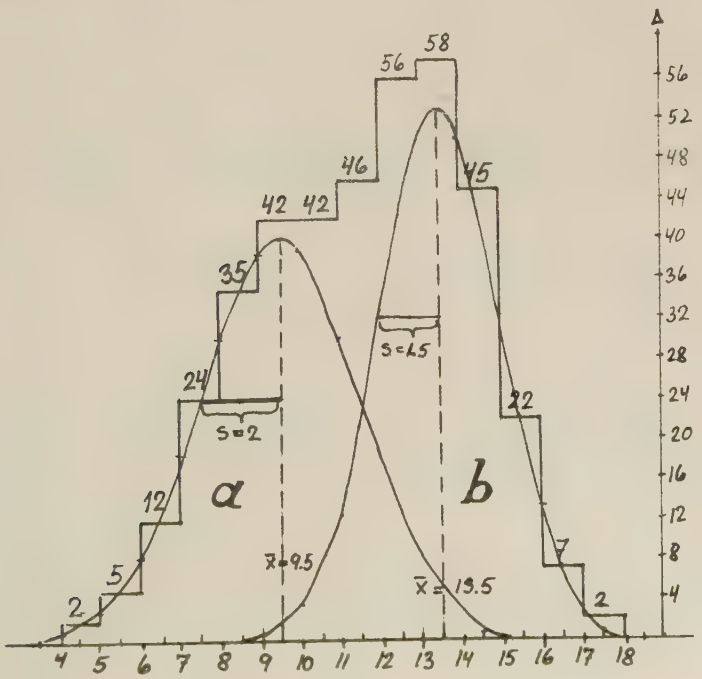


Fig. 18.2.2a

Exercise 2.3 **Confidence limits**

$L - t(30)\ s/\sqrt{n} = 26.22 - 2.04 * 1.284/\sqrt{31} = 25.75$

$L - t(30)\ s/\sqrt{n} = 26.22 + 2.04 * 1.284/\sqrt{31} = 26.69$

Exercise 2.4 **Ordinary linear regression analysis**

Worksheet 2.4

year	i	number of boats x(i)	$x(i)^2$	catch per boat per year y(i)	$y(i)^2$	x(i)*y(i)
1971	1	456	207936	43.5	1892.25	19836.0
1972	2	536	287296	44.6	1989.16	23905.6
1973	3	554	306916	38.4	1474.56	21273.6
1974	4	675	455625	23.8	566.44	16065.0
1975	5	702	492804	25.2	635.04	17690.4
1976	6	730	532900	30.5	930.25	22265.0
1977	7	750	562500	27.4	750.76	20550.0
1978	8	918	842724	21.1	445.21	19369.8
1979	9	928	861184	26.1	681.21	24220.8
1980	10	897	804609	28.9	835.21	25923.3
Total		7146	5354494	309.5	10200.09	211099.5
$\bar{x}$ =		714.6		$\bar{y}$ =	30.95	

$\frac{1}{n} (\Sigma x)^2 = 5106531.6 \qquad \Sigma x^2 - \frac{1}{n} (\Sigma x)^2 = 247962.4$

$\frac{1}{n} (\Sigma y)^2 = 9579.025 \qquad \Sigma y^2 - \frac{1}{n} (\Sigma y)^2 = 621.065$

$\frac{1}{n} (\Sigma x) (\Sigma y) = 221168.7$

$sx^2 = \frac{1}{n-1} [\Sigma x^2 - \frac{1}{n} (\Sigma x)^2] = 27551.38 \qquad sx = 165.99$

$sy^2 = \frac{1}{n-1} [\Sigma y^2 - \frac{1}{n} (\Sigma y)^2] = 69.007 \qquad sy = 8.307$

$sxy = \frac{1}{n-1} [\Sigma xy - \frac{1}{n} (\Sigma x) (\Sigma y)] = - 1118.8$

Slope: $b = sxy/sx^2 = - 0.0406$ Intercept: $a = \bar{y} - b\bar{x} = 59.96$

Variance of b:

$sb^2 = \frac{1}{n-2} [(sy/sx)^2 - b^2] = 0.000107 \qquad sb = 0.01034$

Variance of a:

$sa^2 = sb^2 (\frac{n-1}{n} sx^2 + \bar{x}^2) = 57.272 \qquad sa = 7.568$

Students distribution: t(n-2) = 2.31

Confidence limits:

b - sb * t(n-2), b + sb * t(n-2) = [- 0.0645 , - 0.0167]

a - sa * t(n-2), a + sa * t(n-2) = [42.5 , 77.4]

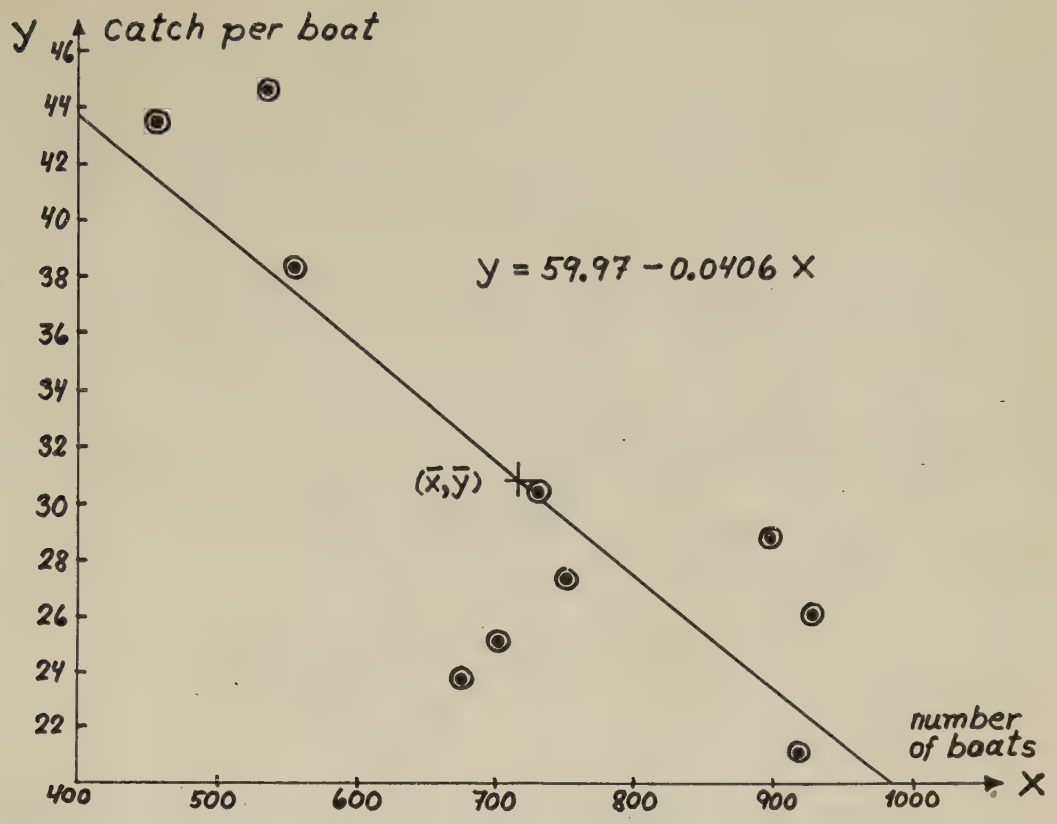


Fig. 18.2.4

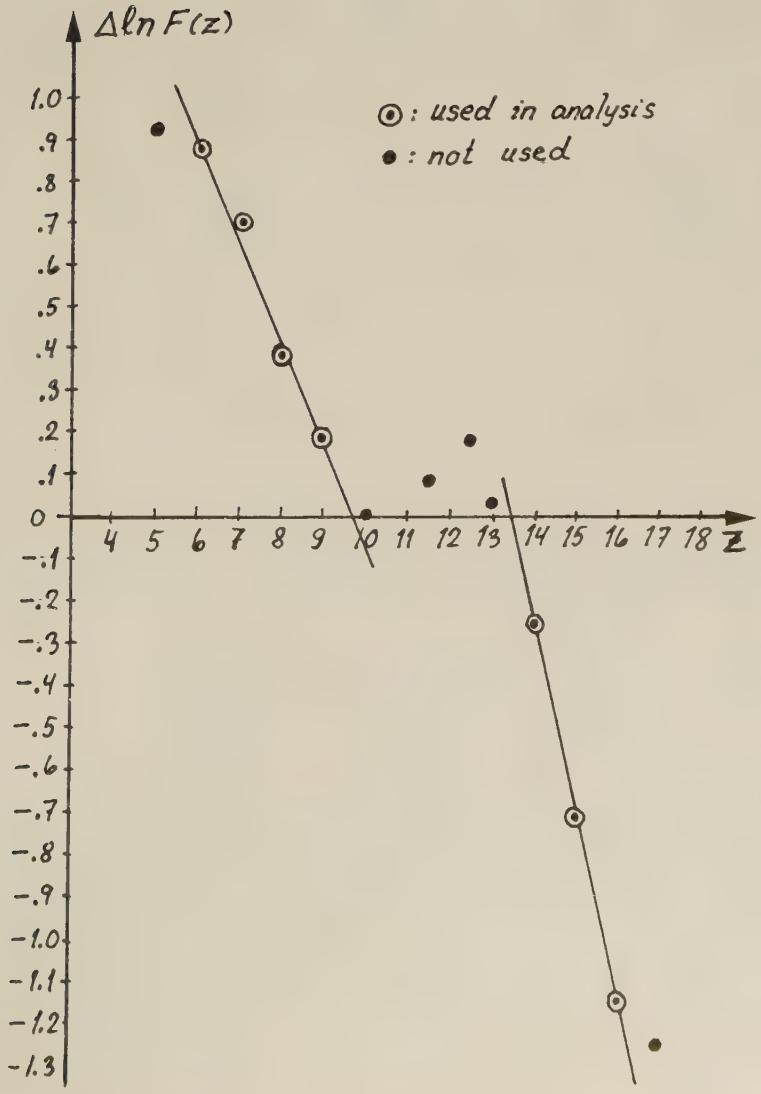


Fig. 18.2.6

Exercise 2.5 The correlation coefficient

In principle the number of boats can be measured with any accuracy, so this is the natural independent variable. The correlation coefficient is not considered useful in the present context. Nevertheless, as an exercise we calculate the confidence limits:

$A = 0.5 \ln[(1+r)/(1-r)] = 0.5 \ln[(1 - 0.811)/(1 + 0.811)] = -1.131$

$B = 1.96/\sqrt{n-3} = 1.96/\sqrt{7} = 0.741$

$\tanh(A-B) = -0.95, \qquad \tanh(A+B) = -0.37$

Exercise 2.6 Linearizing transformations, the Bhattacharya plot

Worksheet 2.6

x	F(x)	ln F(x)	/\ ln F(z)	z	
4.5	2	0.693			
			0.916	5	
5.5	5	1.609			
			0.875	6	
6.5	12	2.485			
			0.693	7	
7.5	24	3.178			
			0.377	8	
8.5	35	3.555			
			0.182	9	
9.5	42	3.737			
			0.000	10	
10.5	42	3.737			
			0.091	11	contami-
11.5	46	3.829			
			0.197	12	nated
12.5	56	4.025			
			0.035	13	
13.5	58	4.060			
			-0.254	14	
14.5	45	3.807			
			-0.716	15	
15.5	22	3.091			
			-1.145	16	
16.5	7	1.946			
			-1.253	17	
17.5	2	0.693			

	first component	second component
intercept (a)	2.328	5.978
slope (b)	-0.240	-0.446
$\bar{x} = -a/b$	9.7	13.4
$s^2 = -1/b$	4.18	2.24
s	2.04	1.50

Points on the left hand side of the normal distribution appear above the x-axis on the Bhattacharya plot and points on the right hand side of the normal distribution appear below the x-axis, or in other words:

/\ ln Fc(z) > 0 for the ascending part of the normal curve

/\ ln Fc(z) < 0 for the decending part of the normal curve

Exercise 2.8 Stratified random sampling versus simple random sampling and proportional sampling

Worksheet 2.8

stratum j	s(j)	$s(j)^2$	N(j)	$\Sigma_i Y(i,j)^2$	$\Sigma_i Y(i,j)$
1 large	28.906	835.57	10	25413	423
2 medium	8.569	73.43	30	9091	457
3 small	2.809	7.89	60	1524	252
Total:			100	36028	1132

$$\text{Total } s^2 = \frac{\Sigma\Sigma Y(i,j)^2 - (1/N)(\Sigma\Sigma Y(i,j))^2}{N-1} = 234.48$$

a)

$$\text{VARran}(\bar{Y}) = \frac{s^2}{n} * \frac{N-n}{N} = \frac{234.48}{20} * \frac{80}{100} = 9.38$$

b) $\text{VARprop}(\bar{Y}) =$

$$\frac{1}{100^2} * \left[\frac{10(10-2)}{2} s(1)^2 + \frac{30(30-6)}{6} s(2)^2 + \frac{60(60-12)}{12} s(3)^2 \right] =$$

$$\frac{1}{10000} * (40 * 835.57 + 120 * 73.43 + 240 * 7.89) = 4.41$$

c) Optimum stratified sampling:

stratum j	s(j) * N(j)	$\frac{s(j) * N(j)}{\Sigma s(j) * N(j)}$	$n \frac{s(j) * N(j)}{\Sigma s(j) * N(j)} = n(j)$
1 large	289.06	0.40	8
2 medium	257.07	0.36	7
3 small	168.55	0.24	5
Total:	714.68	1.00	n = 20

$\text{VARopt}(\bar{Y}) =$

$$\frac{1}{10000} * \left[\frac{10(10-8)}{8} 835.57 + \frac{30(30-7)}{7} 73.43 + \frac{60(60-5)}{5} 7.89 \right] = 1.45$$

	random	proportional	optimum
$s = \sqrt{VAR}$	3.06	2.10	1.20

Allocation

stratum 1 (large)	?	2	8
" 2 (medium)	?	6	7
" 3 (small)	?	12	5

Exercise 3.1 The von Bertalanffy growth equation

Worksheet 3.1

age	standard length	body weight	total length
0.5	1.0	0.04	1.4
1.0	6.6	9	8.0
1.5	11.8	45	14.1
2	16.5	118	19.7
3	24.9	380	29.6
4	32.0	775	37.9
5	38.0	1262	45.0
6	43.0	1802	51.0
7	47.3	2359	56.0
8	50.9	2909	60.3
9	54.0	3434	63.9
10	56.6	3922	67.0
12	60.6	4770	71.7
14	63.5	5444	75.1
16	65.5	5961	77.5
20	68.1	6637	80.5
50	70.7	7388	83.6

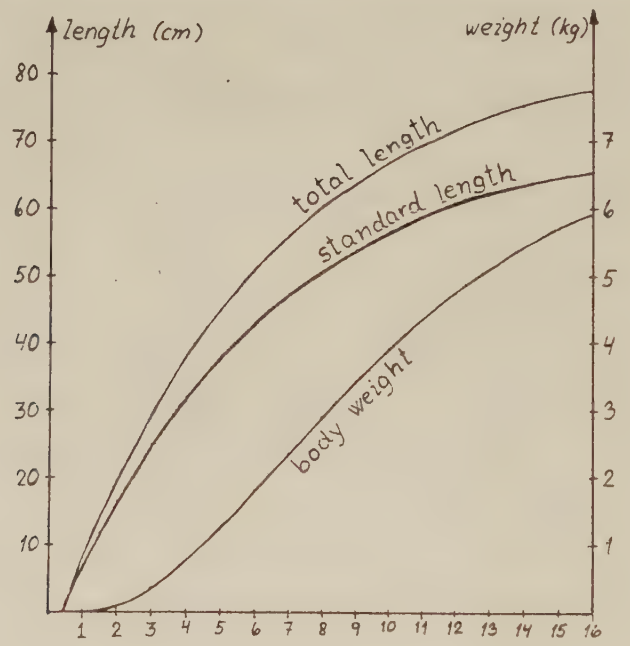


Fig. 18.3.1

Exercise 3.2.1 Data from age readings and length compositions (age/length key)

Worksheet 3.2.1

cohort length interval	1982 S	1981 A	1981 S	1980 A	number in length sample	1982 S	1981 A	1981 S	1980 A
35-36	0.800	0.200	0	0	53	42.4	10.6	0	0
36-37	0.636	0.273	0.091	0	61	38.8	16.7	5.6	0
37-38	0.600	0.300	0.100	0	49	29.4	14.7	4.9	0
38-39	0.500	0.400	0.100	0	52	26.0	20.8	5.2	0
39-40	0.364	0.364	0.182	0.091	70	25.5	25.5	12.7	6.4
40-41	0.273	0.455	0.182	0.091	52	14.2	23.7	9.5	4.7
41-42	0.222	0.444	0.222	0.111	49	10.9	21.8	10.9	5.4
				total	386	187.2	133.8	48.8	16.5

Exercise 3.3.1 The Gulland and Holt plot

Worksheet 3.3.1

A	B	C	D	E (y)	F (x)
fish no.	L(t) cm	L(t+/\t) cm	/\t days	/\L / /\t cm/year	L(t)+L(t+/\t) / 2 cm
1	9.7	10.2	53	3.44	9.95
2	10.5	10.9	33	4.42	10.70
3	10.9	11.8	108	3.04	11.35
4	11.1	12.0	102	3.22	11.55
5	12.4	15.5	272	4.16	13.95
6	12.8	13.6	48	6.08	13.20
7	14.0	14.3	53	2.07	14.15
8	16.1	16.4	73	1.50	16.25
9	16.3	16.5	63	1.16	16.40
10	17.0	17.2	106	0.69	17.10
11	17.7	18.0	111	0.99	17.85

a (intercept) = 8.77 b (slope) = - 0.431
K = -b = 0.43 per year L_∞ = - a/b = 20.3 cm

$$sb^2 = \frac{1}{n-2}\left[(sy/sx)^2 - b^2\right] = \frac{1}{9}\left[(1.68869/2.75716)^2 - 0.43120^2\right] = 0.02102$$

sb = 0.145 t(9) = 2.26
Confidence interval of K: [0.10 , 0.76]

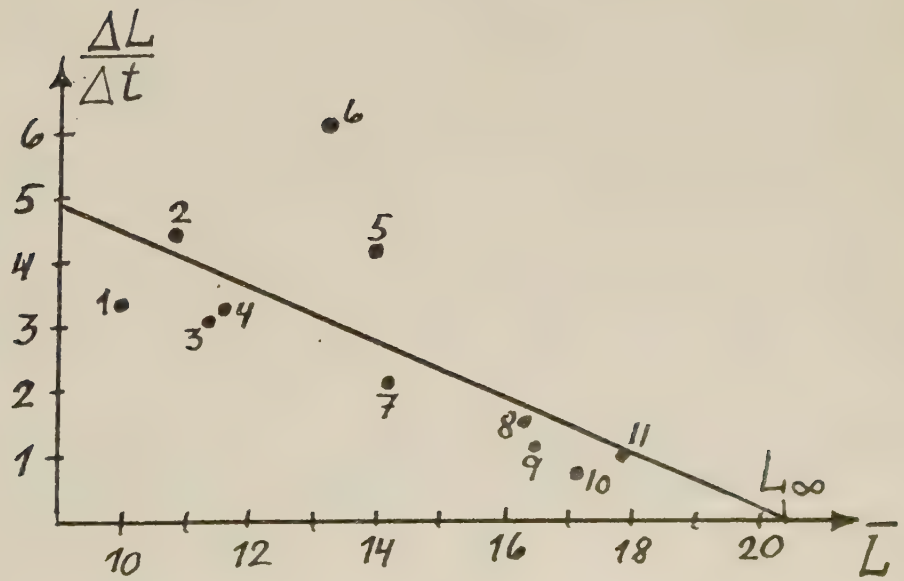


Fig. 18.3.3.1

Exercise 3.3.2 The Ford-Walford plot (and Gulland and Holt plot)

Worksheet 3.3.2

method	FORD-WALFORD		GULLAND AND HOLT	
t	L(t)	L(t+/\t)	/\L//\t	$\bar{L}$
1	35	55	20	45
2	55	75	20	65
3	75	90	15	82.5
4	90	105	15	97.5
5	105	115	10	110.0
a (intercept)	26.2		28.0	
b (slope)	0.86		-0.15	
$sb^2 = \frac{1}{n-2}[(sy/sx^2) - b^2]$	0.0009268		0.001240	
t(n-2) = t(3) = 3.18 confidence limits of b:	[0.76 , 0.96]		[-0.26 , -0.04]	
K	- ln b/\t = 0.15 ln confidence limits: [0.05,0.27]		- b = 0.15	
L_∞	a/(1-b) = 185 cm		- a/b = 187 cm	

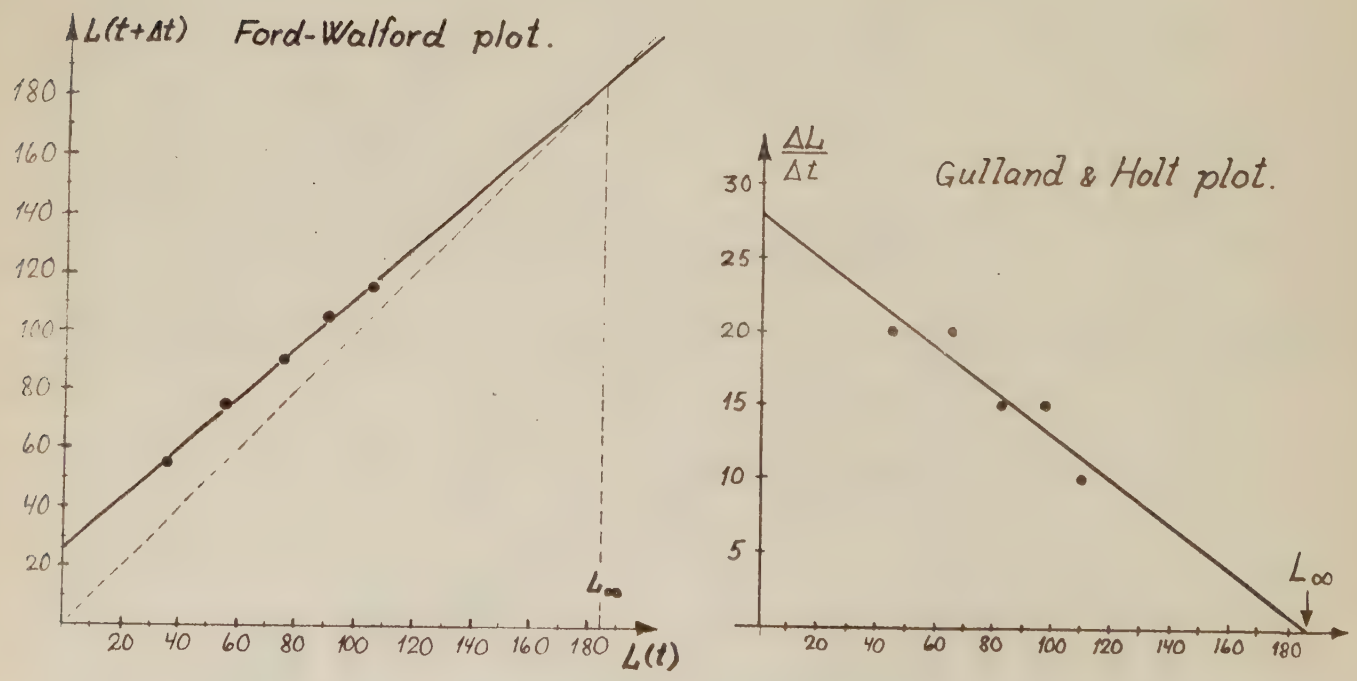


Fig. 18.3.3.2

Exercise 3.3.3 The von Bertalanffy plot

We choose as estimate for L_∞ 11 inches. (Very few, 1.5% of the snappers are longer than 11 inches).

We assign the arbitrary ages of 1,2,3 and 4 years to the four age groups.

age	L	$-\ln(1 - L/L_\infty)$
1	3.22	0.35
2	5.33	0.66
3	7.62	1.18
4	9.74	2.17

b (slope) = K = 0.60 per year

At least, K has now got the correct sign.

$sb^2 = 0.0119$, $sb = 0.109$, $t(2) = 4.3$

Confidence interval of K: [0.13 , 1.07]

t_o cannot be estimated because the absolute age is not known.

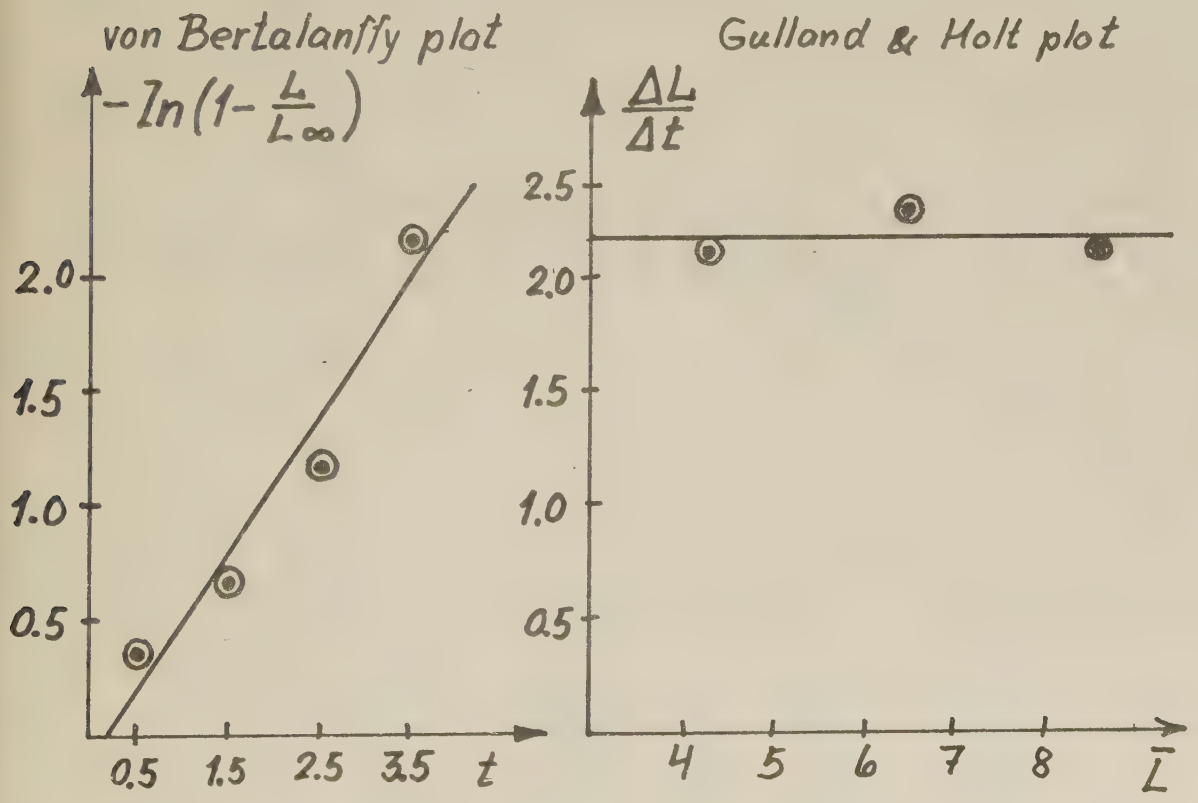


Fig. 18.3.3.3

Exercise 3.3.6 The weight converted von Bertalanffy growth equation

Worksheet 3.3.6

t	L(t)	w(t)	t	L(t)	t
0	2.54	0.38	0.9	9.34	19.00
0.1	3.63	1.11	1.0	9.78	21.83
0.2	4.62	2.29	1.2	10.55	27.36
0.3	5.51	3.90	1.4	11.17	32.53
0.4	6.32	5.88	1.6	11.69	37.21
0.5	7.05	8.16	1.8	12.11	41.37
0.6	7.71	10.69	2.0	12.45	44.99
0.7	8.31	13.37	2.5	13.06	51.93
0.8	8.85	16.16	3.0	13.43	56.47

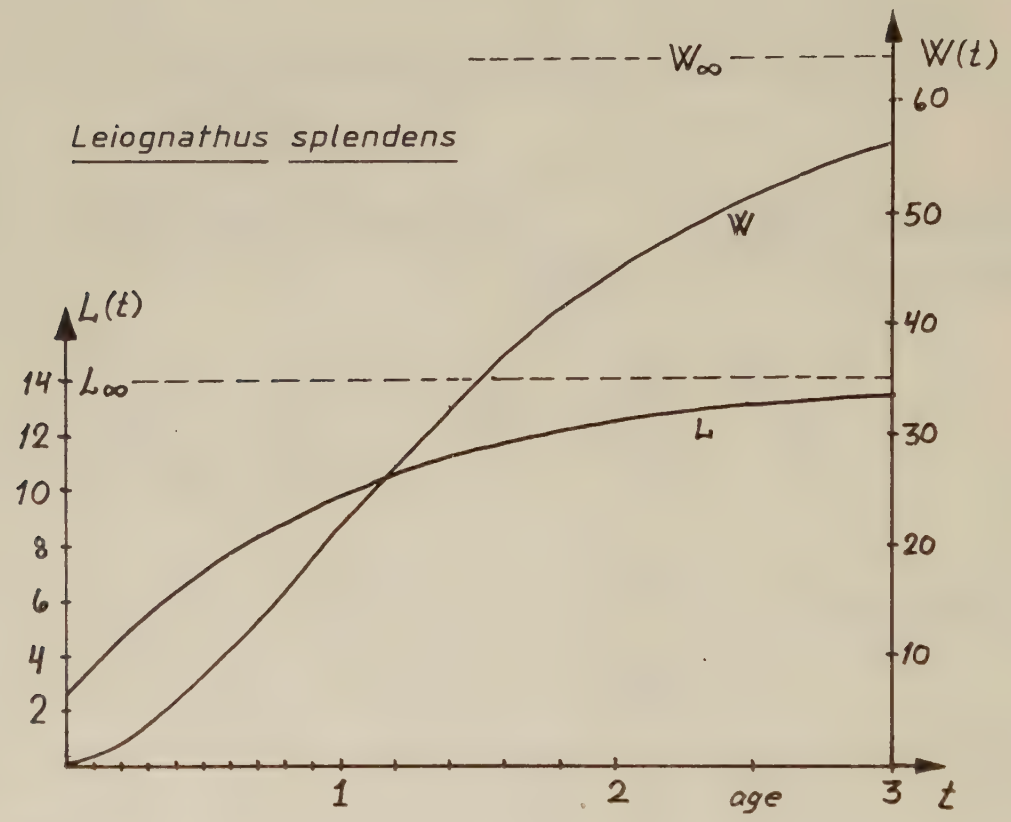


Fig. 18.3.3.6

Exercise 3.4.1 Bhattacharya's method

There is no "correct" solution to this exercise. The following is a "suggestion for a solution". It is not the same result as Weber and Jothy (1977) got by using the Cassie method.

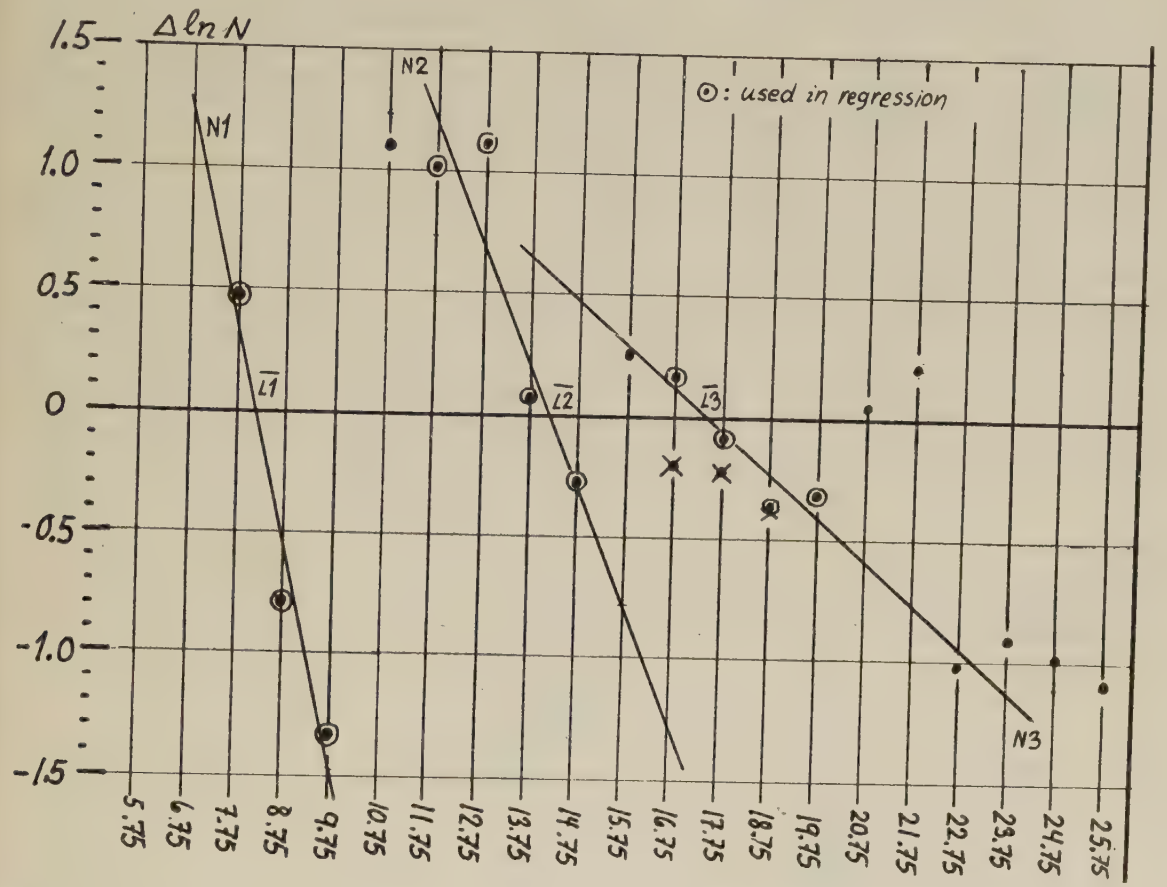


Fig. 18.3.4.1A

Worksheet 3.4.1a

A	B	C	D	E	F	G	H	I
interval	N1+	ln N1+	/\ln N1+	L	/\ln N1c	ln N1c	N1	N2+
5.75- 6.75	1	0	-	-	-	-	1	-
6.75- 7.75s	26	3.258	(3.258)	6.75	1.262	("clean")	26	0
7.75- 8.75	42	3.738s	0.480*	7.75	0.354	3.738	42	0
8.75- 9.75	19s	2.944	-0.793*	8.75	-0.554	3.183	19	0
9.75-10.75	5	1.609	-1.335*	9.75	-1.462	1.722	5	0
10.75-11.75	15	2.708	1.099	10.75	-2.370	-0.648	0.5	14.5
11.75-12.75	41	3.714	1.006	11.75	-3.278	-3.926	0.0	41.0
12.75-13.75	125	4.828	1.115	12.75	-	-	-	125
13.75-14.75	135	4.905	0.077	13.75	-	-	-	135
.....								
Total	1069						93.5	

a (intercept) = 7.391 b (slope) = - 0.908

$\bar{L}1 = -a/b = 8.14$ $s = \sqrt{-1/b} = 1.05$

Worksheet 3.4.1d

A	B	C	D	E	F	G	H	I
interval	N4+	ln N4+	/\ln N4+	L	/\ln N4c	ln N4c	N4	N5+
.....								
20.75-21.75	20.2	3.006	-	20.75	?			
21.75-22.75	44.4	3.793	0.787	21.75	?	too few		
22.75-23.75	15.5	2.741	-1.052	22.75	?	observations		
23.75-24.75	6.5	1.892	-0.869	23.75	?			
24.75-25.75	2.6	0.956	-0.916	24.75	?			
25.75-26.75	1	0	-0.956	25.75	?			

Gulland and Holt plot:

age	$\bar{L}i$	/\L//\t	$\bar{L}$
1	8.1		
		6.1	11.15
2	14.2		
		3.3	15.85
3	17.5		

a (intercept) = 12.7 b (slope) = - 0.60

K = - b = 0.60 per year L_∞ = - a/b = 21.4 cm

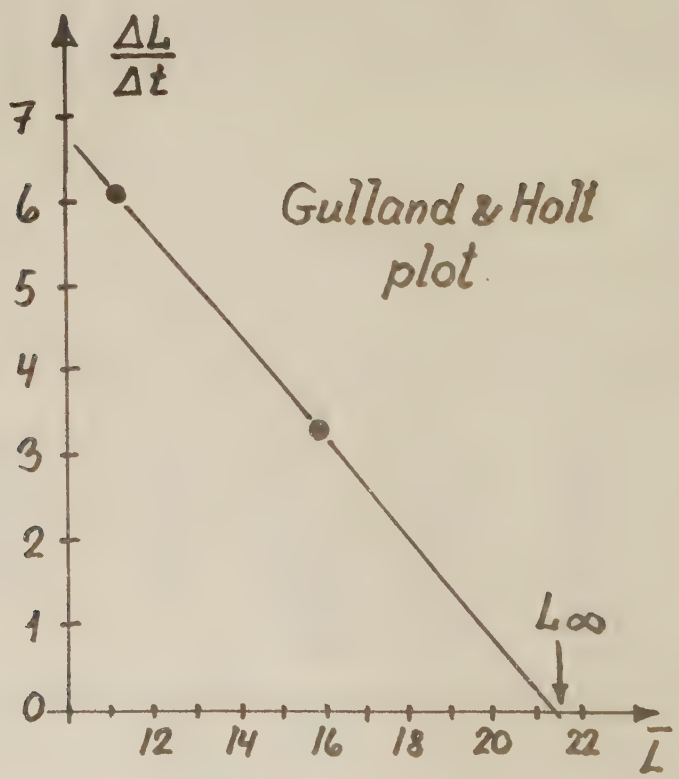


Fig. 18.3.4.1B

Exercise 3.4.2 Modal progression analysis

Leiognathus splendens:

Worksheet 3.4.2

	GULLAND AND HOLT PLOT			VON BERTALANFFY PLOT	
Time of sampling	L(t)	$\Delta L/\Delta t$	$\bar{L}$	t	$-\ln(1 - L/L_\infty)$
1 June	2.8			0.42	0.325
		6.8	3.65		
1 Sep.	4.5			0.67	0.590
		5.2	5.15		
1 Dec.	5.8			0.92	0.854
		4.0	6.30		
1 March	6.8			1.17	1.119
a (intercept)		10.65		-0.12	
b (slope, K)		-1.06		1.06	
-a/b		L_∞ = 10.1		t_o = 0.11	

$L(t) = 10.1\ [1 - \exp(-1.1(t - 0.11))]$

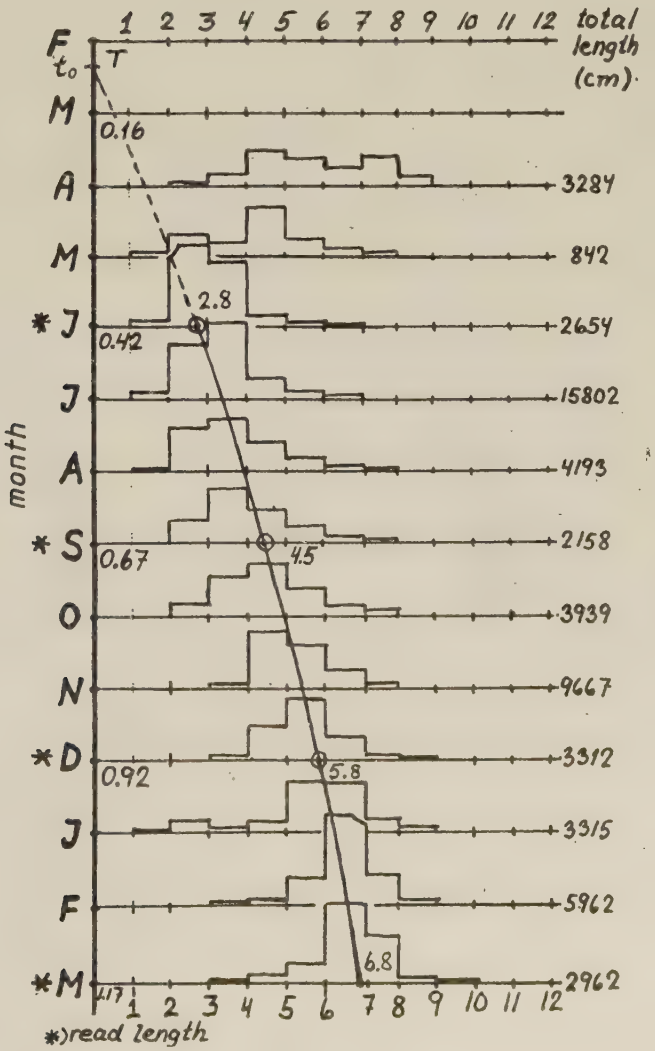


Fig. 18.3.4.2A

Rastrelliger kanagurta:

	GULLAND AND HOLT PLOT			VON BERTALANFFY PLOT	
Time of sampling	L(t)	$\Delta L/\Delta t$	$\bar{L}$	t	$-\ln(1 - L/L_\infty)$
1 Feb.	13.3			0.08	0.648
		21.6	14.20		
1 March	15.1			0.17	0.779
		17.4	16.55		
1 May	18.0			0.33	1.036
		16.8	18.70		
1 June	19.4			0.42	1.189
		13.2	19.95		
1 July	20.5			0.50	1.327
		9.6	20.9		
1 August	21.3			0.58	1.442
a (intercept)		44.57		0.512	
b (slope, K)		-1.60		1.61	
-a/b		L_∞ = 27.9		t_o = -0.32	

$L(t) = 27.9\ [1 - \exp(-1.6(t + 0.32))]$

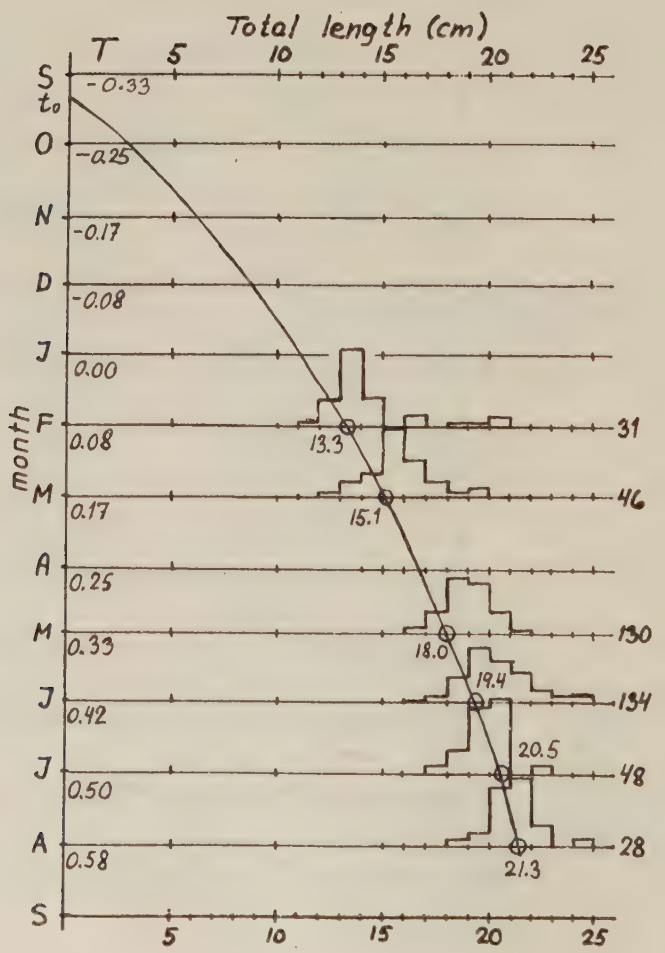


Fig. 18.3.4.2 B

Exercise 3.5.1 ELEFAN I

Worksheet 3.5.1

RESTRUCTURING OF LENGTH FREQUENCY SAMPLE

mid-lgt. L	orig. freq. FRQ(L)	STEP 1 MA(L)	STEP 2 FRQ/MA	STEP 3 FRQ/MA/M-1	STEP 4a	STEP 4b	STEP 5	STEP 6
5	4	4.6	0.870	-0.197	2	-0.197	-0.109	
10	13	4.6	2.826	1.610	2	0.966	0.966	0.966
15	6	4.8	1.250	0.154	1	0.124	0.124	
20	0	4.0	0	-1.000	-	-1.000	0	
25	1	1.4	0.714	-0.340	3	-0.340	-0.188	
30	0	0.4	0	-1.000	-	-1.000	0	
35	0	1.0	0	-1.000	-	-1.000	0	
40	1	1.0	1.000	-0.076	2	-0.076	-0.042	
45	3	1.0	3.000	1.771	2	1.062	1.062	1.062
50	1	1.2	0.833	-0.230	1	-0.230	-0.127	
55	0	1.0	0	-1.000	-	-1.000	0	
60	1	0.4	2.500	1.309	3	0.524	0.524	0.524

Σ = 12.993 SP: 2.676

(Σ/12) = M: 1.083 SN: -4.843 ASP: 2.552

-SP/SN = R: 0.553

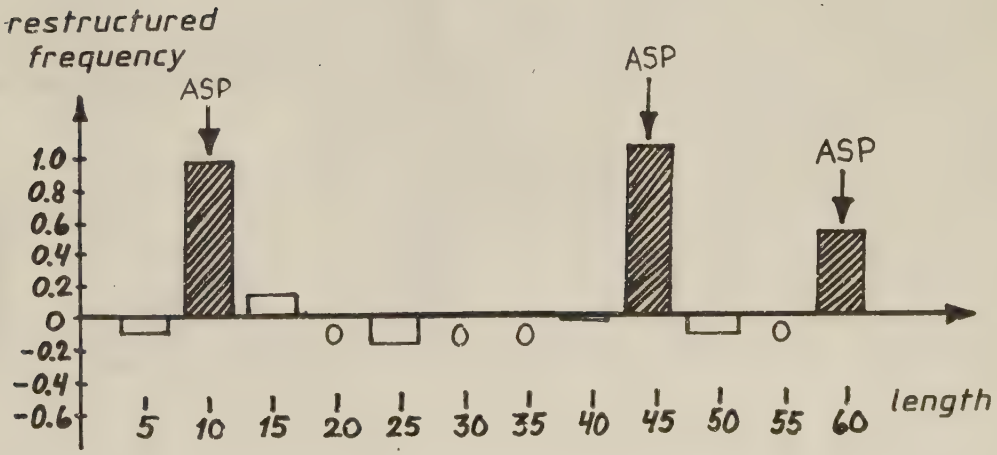


Fig. 18.3.5.1

Exercise 3.5.1a **ELEFAN I, continued**

Worksheet 3.5.1a

mid-lgt. L	orig. freq. FRQ(L)	STEP 1 MA(L)	STEP 2 FRQ/MA	STEP 3 FRQ/MA/M-1	STEP 4a	STEP 4b	STEP 5	STEP 6
20	14	18.2	0.769	-0.194	2	-0.194	-0.159	
24	32	40.0	0.800	-0.162	1	-0.162	-0.133	
28	45	63.0	0.714	-0.252	0	-0.252	-0.206	
32	109	75.8	1.438	0.506	0	0.506	0.506	
36	115	78.4	1.467	0.537	0	0.537	0.537	0.537
40	78	75.2	1.037	0.086	0	0.086	0.086	
44	45	58.0	0.776	-0.187	0	-0.187	-0.153	
48	29	37.2	0.780	-0.183	0	-0.183	-0.150	
52	23	24.0	0.958	0.003	0	0.003	0.003	0.003
56	11	16.0	0.688	-0.279	0	-0.279	-0.228	
60	12	10.6	1.132	0.186	0	0.186	0.186	0.186
64	5	6.2	0.806	-0.156	0	-0.156	-0.128	
68	2	4.4	0.455	-0.523	0	-0.523	-0.428	
72	1	2.0	0.500	-0.476	1	-0.476	-0.390	
76	2	1.0	2.000	1.095	2	0.657	0.657	0.657

Σ = 14.320 SP: 1.975

(Σ/15) = M : 0.9547 SN: -2.413 ASP: 1.383

-SP/SN = R: 0.818

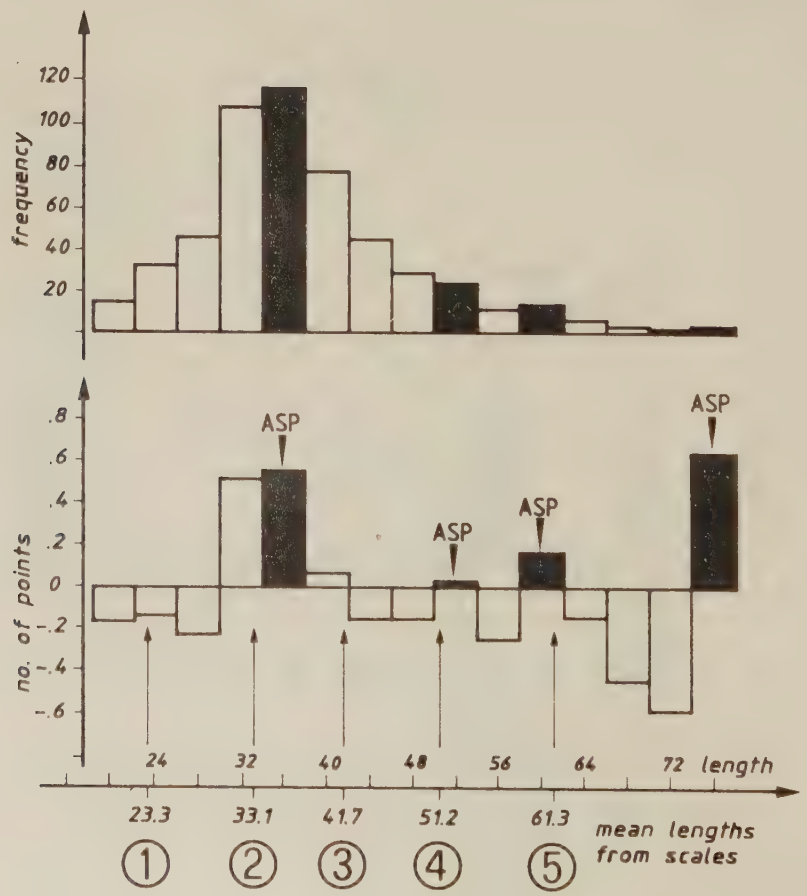


Fig. 18.3.5.1a *Fig. 18. 3. 5. 1a*

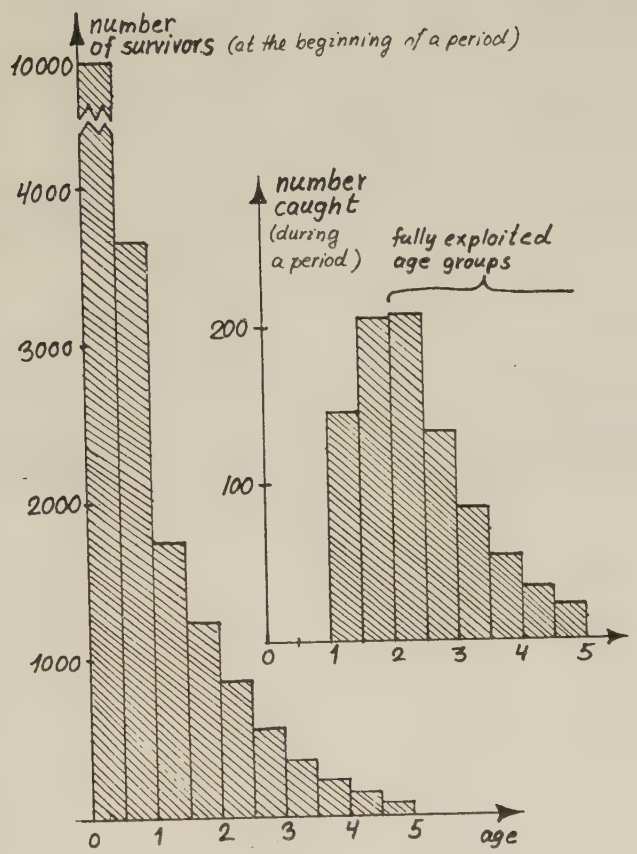
Exercise 4.2 The dynamics of a cohort (exponential decay model with variable Z)

Worksheet 4.2

t	M	F	Z	$e^{-0.5Z}$	N(t)	N(t)-N(t+0.5)	F/Z	C
0.0-0.5	2.0	0.0	2.0	0.3679	10000	6321	0	0
0.5-1.0	1.5	0.0	1.5	0.4724	3679	1941	0	0
1.0-1.5	0.5	0.2	0.7	0.7047	1738	513	0.286	147
1.5-2.0	0.3	0.4	0.7	0.7047	1225	362	0.571	207
2.0-2.5	0.3	0.6	0.9	0.6376	863	313	0.667	209
2.5-3.0	0.3	0.6	0.9	0.6376	550	199	0.667	133
3.0-3.5	0.3	0.6	0.9	0.6376	351	127	0.667	85
3.5-4.0	0.3	0.6	0.9	0.6376	224	81	0.667	54
4.0-4.5	0.3	0.6	0.9	0.6376	143	52	0.667	35
4.5-5.0	0.3	0.6	0.9	0.6376	91	33	0.667	22

(58)

Fig. 18.4.2



Exercise 4.2a The dynamics of a cohort (the formula for average number of survivors, Eq. 4.2.9)

The formula for average number of survivors (Eq. 4.2.9).

Exact value:

$$N(2.0,5.0) = 863 \frac{1}{0.9 * 3.0} [1 - \exp(-0.9 * 3.0)] = 298$$

Approximation:

$$N(2.0,5.0) = (863+550+351+224+143+91+58)/7 = 326$$

Exercise 4.3 Estimation of Z from CPUE data

Worksheet 4.3

	cohort	1982 A	1982 S	1981 A	1981 S	1980 A
	age t2	1.16	1.65	2.10	2.64	3.21
	CPUE	111	67	40	24	15

co-hort	age t1	CPUE					
83 S	0.64	182	0.95	0.99	1.04	1.01	0.97
82 A	1.16	111	-	1.03	1.09	1.03	0.98
82 S	1.65	67	-	-	1.15	1.04	0.96
81 A	2.10	40	-	-	-	0.95	0.88
81 S	2.64	24	-	-	-	-	0.82

Exercise 4.4.3 The linearized catch curve based on age composition data

Worksheet 4.4.3

age t	year y	C(y,t,t+1)	ln C(y,t,t+1)	Remarks
0	1974	599	6.395	
1	1975	860	6.757	not used
2	1976	1071	6.976	
3	1977	269	5.596	
4	1978	69	4.234	used in
5	1979	25	3.219	the
6	1980	8	2.079	analysis
7	1981	-	-	

slope: b = - 1.16 $\quad sb^2 = [(sy/sx)^2 - b^2]/(n-2) = 0.002330$

sb = 0.0483 $\quad$ sb t(n-2) = 0.0483 * 4.30 = 0.21 $\quad$ Z = 1.16 ± 0.21

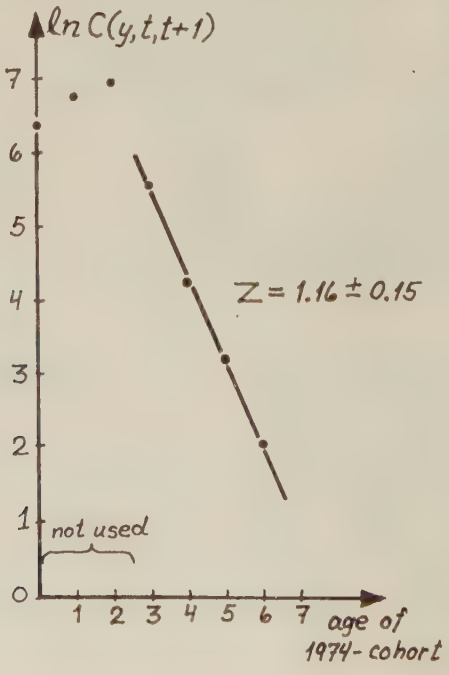


Fig. 18.4.4.3

Exercise 4.4.5 The linearized catch curve based on length composition data

Worksheet 4.4.5

L1-L2	C(L1,L2)	t(L1)	Δt	$t(\frac{L1+L2}{2})$	$\ln \frac{C(L1,L2)}{\Delta t}$	Z	remarks
7 -8	11	0.452	0.0759	0.489	4.976	-	
8 -9	69	0.527	0.0796	0.567	6.765	-	
9-10	187	0.607	0.0836	0.648	7.712	-	not
10-11	133	0.691	0.0881	0.734	7.319	-	used
11-12	114	0.779	0.0931	0.825	7.110	-	
12-13	261	0.872	0.0987	0.921	7.880	-	
13-14	386	0.971	0.1050	1.022	8.210	-	
14-15	445	1.076	0.112	1.13	8.286	-	
15-16	535	1.188	0.120	1.25	8.400	-	
16-17	407	1.308	0.130	1.37	8.051	-	
17-18	428	1.438	0.141	1.51	8.019	1.43	
18-19	338	1.579	0.154	1.65	7.693	1.60	used in
19-20	184	1.733	0.170	1.82	6.987	2.27	analysis
20-21	73	1.903	0.190	2.00	5.953	3.07	
21-22	37	2.092	0.214	2.20	5.152	3.45	
22-23	21	2.307	0.246	2.43	4.446	3.54	
23-24	19	2.553	0.290	2.69	4.183	3.30	
24-25	8	2.843	0.352	3.01	3.124	3.20	
25-26	7	3.195	0.448	3.40	2.749	-	too close
26-27	2	3.643	0.617	3.92	1.176	-	to L_∞

Details of the regression analyses:

L1-L2	Z	number of obs. n	Students distrib. t(n-2)	variance of slope sb^2	confidence limits Z ± t(n-2) sb
15-16	-	1	-	-	-
16-17	-	2	-	-	-
17-18	1.43	3	12.70	0.59	1.43 ± 9.76
18-19	1.60	4	4.30	0.12	1.60 ± 1.49
19-20	2.27	5	3.18	0.156	2.27 ± 1.26
20-21	3.07	6	2.78	0.228	3.07 ± 1.33
21-22	3.45	7	2.57	0.140	3.45 ± 0.96
22-23	3.54	8	2.45	0.071	3.54 ± 0.65
23-24	3.30	9	2.37	0.051	3.30 ± 0.54
24-35	3.20	10	2.31	0.030	3.20 ± 0.40

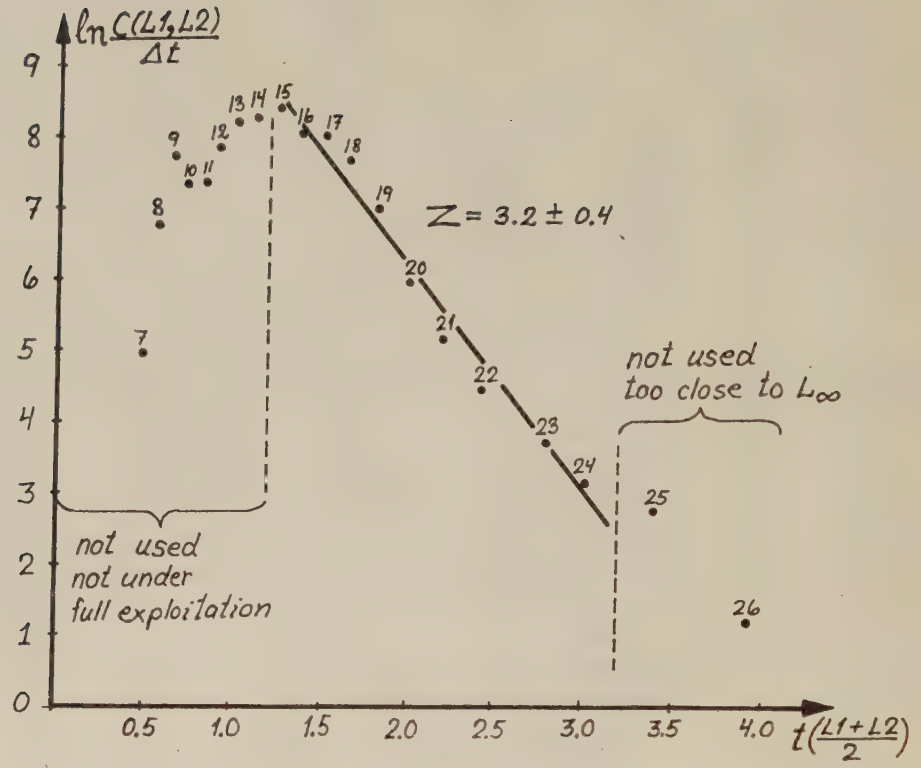


Fig. 18.4.4.5

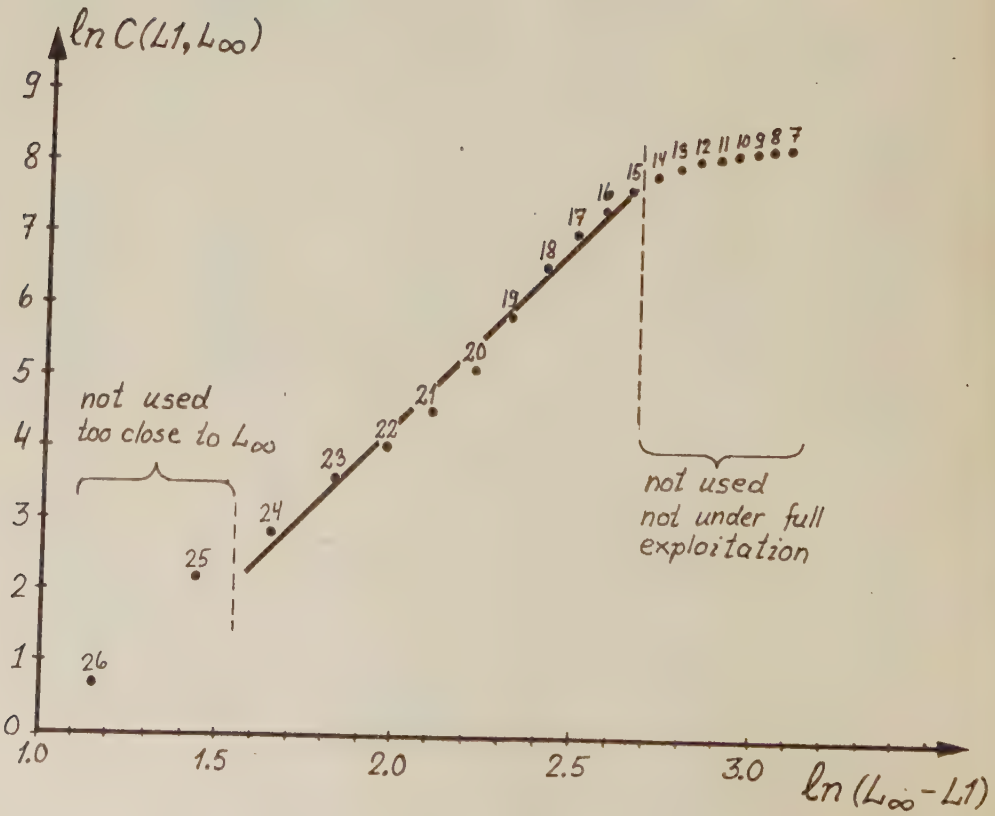


Fig. 18.4.4.6

Exercise 4.4.6 The cumulated catch curve based on length composition data (the Jones and van Zalinge method)

Worksheet 4.4.6

L1-L2	C(L1,L2)	cumulated $C(L1,L_\infty)$	(y) $\ln C(L1,L_\infty)$	(x) $\ln(L_\infty-L1)$	slope Z/K	remarks
7- 8	11	3665	8.207	3.100	-	
8- 9	69	3654	8.204	3.054	-	
9-10	187	3585	8.185	3.006	-	not
10-11	133	3398	8.131	2.955	-	used
11-12	114	3265	8.091	2.901	-	
12-13	261	3151	8.055	2.845	-	
13-14	386	2890	7.969	2.785	-	
14-15	445	2504	7.825	2.721	-	
15-16	535	2059	7.630	2.653	-	
16-17	407	1524	7.329	2.580	-	
17-18	428	1117	7.018	2.501	4.03	
18-19	338	689	6.535	2.416	4.56	
19-20	184	351	5.861	2.322	5.28	used in
20-21	73	167	5.118	2.219	5.81	analysis
21-22	37	94	4.543	2.104	5.86	
22-23	21	57	4.043	1.974	5.62	
23-24	19	36	3.584	1.825	5.25	
24-25	8	17	2.833	1.649	5.00	
25-26	7	9	2.197	1.435	-	too close
26-27	2	2	0.693	1.163	-	to L_∞

Details of the regression analyses:

L1-L2	Z	number of obs. n	Students distrib. t(n-2)	variance of slope sb^2	confidence limits Z ± K t(n-2) sb
15-16	-	1	-	-	-
16-17	-	2	-	-	-
17-18	2.44	3	12.70	0.00289	2.44 ± 0.40
18-19	2.77	4	4.30	0.0858	2.77 ± 0.76
19-20	3.20	5	3.18	0.169	3.20 ± 0.79
20-21	3.52	6	2.78	0.141	3.52 ± 0.63
21-22	3.55	7	2.57	0.064	3.55 ± 0.39
22-23	3.41	8	2.45	0.045	3.41 ± 0.32
23-24	3.20	9	2.37	0.056	3.20 ± 0.34
24-35	3.03	10	2.31	0.045	3.03 ± 0.30

Exercise 4.4.6a The Jones and van Zalinge method applied to shrimp

Worksheet 4.4.6a

carapace length mm L1	numbers landed (millions) C(L1,L2)	cumulated numbers (millions) C(L1,L_∞)	lnC(L1,L_∞)	ln(L_∞-L1)	Z/K	remarks
11.18	2.81	18.16	2.899	3.592	-	
18.55	1.30	15.35	2.731	3.366	-	not
22.15	2.96	14.05	2.643	3.233	-	used
25.27	3.18	11.09	2.406	3.101	-	
27.58	2.00	7.91	2.068	2.992	-	
29.06	1.89	5.91	1.777	2.915	3.36	used in
30.87	1.78	4.02	1.391	2.811	3.52	analysis
33.16	0.98	2.24	0.806	2.663	3.68	
36.19	0.63	1.26	0.231	2.426	3.32	
40.50	0.63	0.63	-0.462	1.946	too close to L_∞	

Details of the regression analyses:

L1	n	t(n-2)	sb^2	Z/K ± t(n-2)sb
29.06	3	12.70	0.0354	3.36 ± 2.39
30.87	4	4.30	0.0143	3.52 ± 0.51
33.16	5	3.18	0.0096	3.68 ± 0.31
36.19	6	2.78	0.0224	3.32 ± 0.42

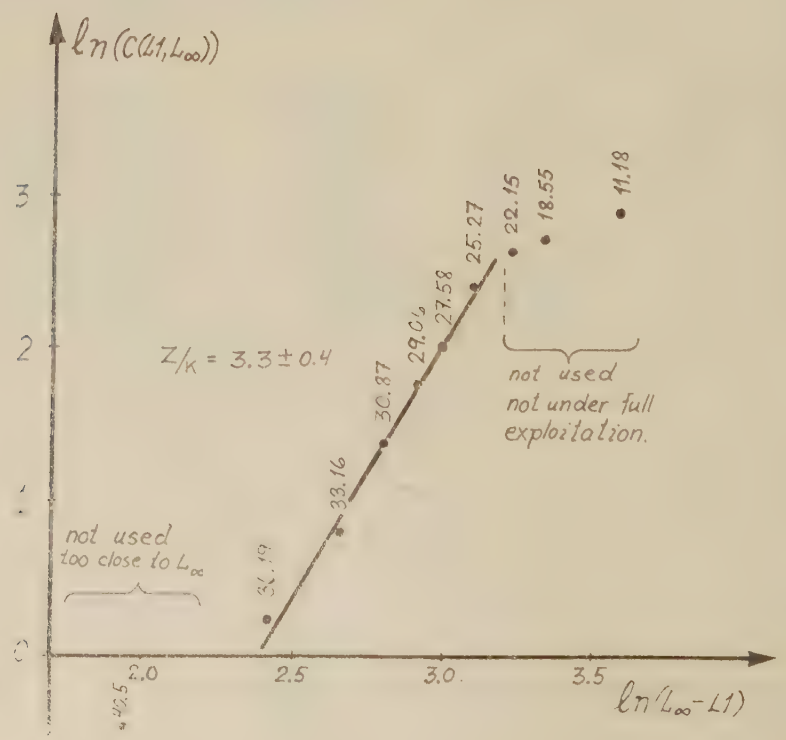


Fig. 18.4.4.6a

Exercise 4.5.1 Beverton and Holt's Z-equation based on length data (applied to shrimp)

Worksheet 4.5.1

carapace length mm L1 = L'	numbers landed (millions) C(L1,L2)	mid-length $\frac{L1+L2}{2}$	C $\frac{L1+L2}{2}$	ΣC	Σ C $\frac{L1+L2}{2}$	$\bar{L}$	Z/K	remarks
11.18	2.81	-	-	-	-	-	-	not
18.55	1.30	-	-	-	-	-	-	used
22.15	2.96	-	-	-	-	-	-	
25.27	3.18	26.43	84.03	11.09	340.15	30.67	3.12	
27.58	2.00	28.32	56.64	7.91	256.12	32.38	3.15	
29.06	1.89	29.97	56.63	5.91	199.48	33.75	2.93	
30.87	1.78	32.02	56.99	4.02	142.85	35.53	2.57	mate-
33.16	0.98	34.68	33.98	2.24	85.86	38.33	1.77	rial
36.19	0.63	38.35	24.16	1.26	51.88	41.17	-	too
40.50	0.63	44.00	27.72	0.63	27.72	44.00	-	small
47.50								

Exercise 4.6 Plot of Z on effort (estimation of M and q)

Worksheet 4.6

year	effort a)	mean length $\overline{Lc}$	$Z = K \frac{L\infty - \overline{Lc}}{\overline{Lc} - Lc}$ (Eq. 4.5.3)
1966	2.08	15.7	1.97
1967	2.80	15.5	2.05
1968	3.50	16.1	1.82
1969	3.60	14.9	2.32
1970	3.80	14.4	2.58
1971	-	no data -	-
1972	-	no data -	-
1973	9.94	12.8	3.74
1974	6.06	12.8	3.74

a) in millions of trawling hours

L_∞ = 29.0 cm K = 1.2 per year Lc = 7.6 cm

a) **Based on data for the years 1966-1970:**

Slope: q = 0.23 ± 0.66 Intercept: M = 1.41 ± 2.11

sq^2 = 0.0424 sM^2 = 0.439

t(3) sq = 3.18 * 0.206 = 0.66 t(3) sM = 3.18 * 0.663 = 2.11

Both confidence intervals contain 0 and negative values which makes no biological sense. The variation in effort is too small to support a dependable regression analysis.

b) Based on data for the years 1966-1974:

Slope: q = 0.27 ± 0.17 Intercept: M = 1.39 ± 0.87

sq^2 = 0.00429 sM^2 = 0.115

t(5) sq = 2.57 * 0.0655 = 0.17 t(5) sM = 2.57 * 0.339 = 0.87

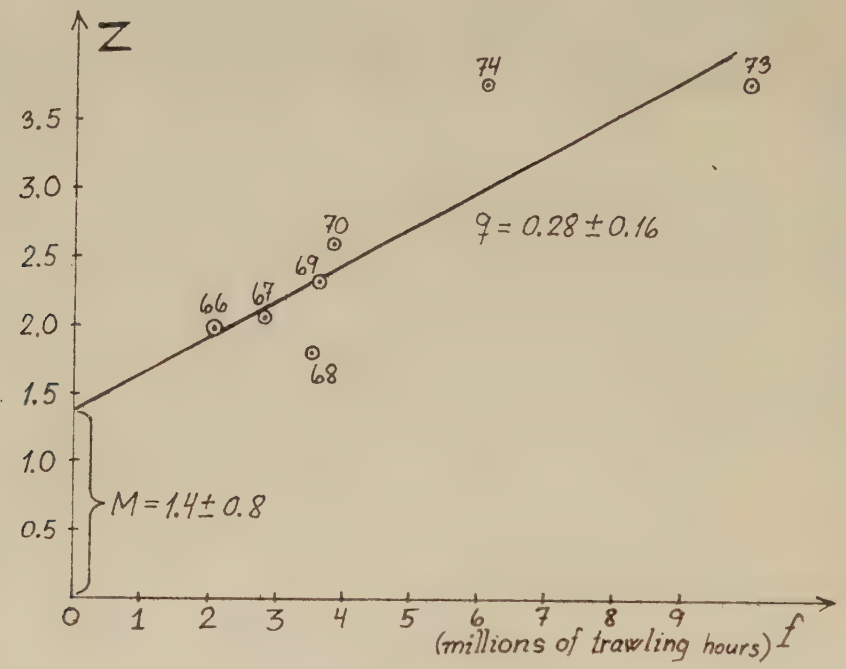


Fig. 18.4.6

Exercise 5.2 Age based cohort analysis (Pope's cohort analysis)

a) F6 = 1.0: C6 = 8

$$N6 = \frac{8}{[1/(1+0.2)]\ [1 - \exp(-1.2)]} = 13.7$$

C5 = 25	N5 = 44.4	F5 = 0.97
C4 = 69	N4 = 130.4	F4 = 0.88
C3 = 269	N3 = 456.6	F3 = 1.05
C2 = 1071	N2 = 1741.3	F2 = 1.14
C1 = 860	N1 = 3077.3	F1 = 0.37
C0 = 599	N0 = 4420.7	F0 = 0.16

b) F6 = 2.0: C6 = 8

$$N6 = \frac{8}{[2/(2+0.2)]\ [1 - \exp(-2.2)]} = 9.9$$

C5 = 25	N5 = 39.7	F5 = 1.18
C4 = 69	N4 = 124.8	F4 = 0.94
C3 = 269	N3 = 449.7	F3 = 1.08
C2 = 1071	N2 = 1732.9	F2 = 1.15
C1 = 860	N1 = 3067.3	F1 = 0.37
C0 = 599	N0 = 4408.0	F0 = 0.16

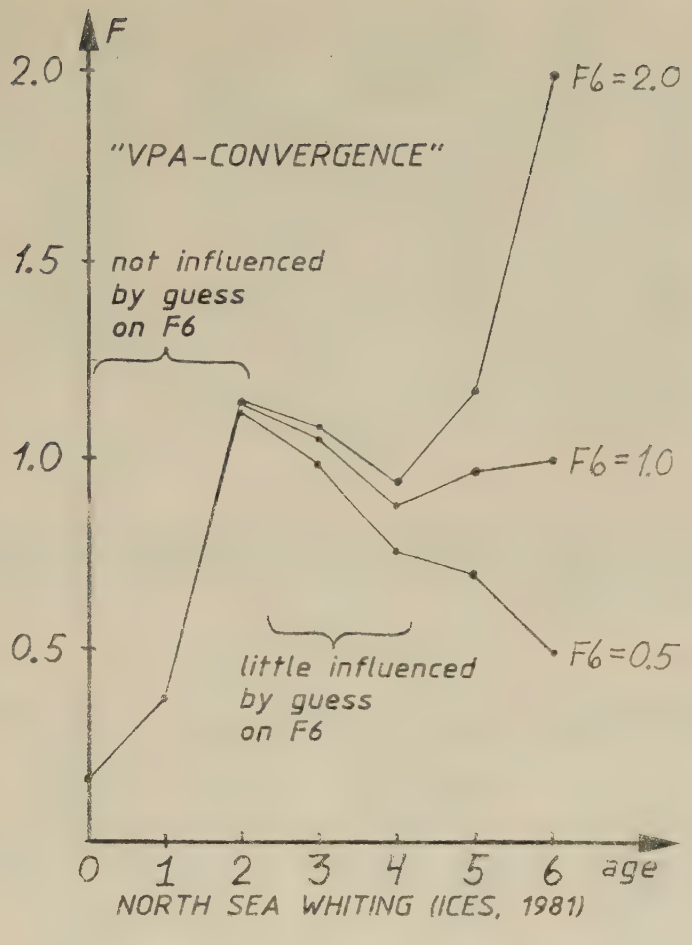


Fig. 18.5.2

Exercise 5.3 A predictive age based model (Thompson and Bell analysis)

Worksheet 5.3

a) No change in fishing effort from 1985 to 1986:

age gr. t	mean wgt. (g) W	beach seine FB	gill net FG	nat. mort. M	tot. mort. Z	stock number N	beach seine catch CB	gill net catch CG	beach seine yield YB	gill net yield YG	total yield YB+YG
0	8	0.05	0.00	2.00	2.05	1000	21.3	0	170	0	170
1	283	0.40	0.00	0.80	1.20	129	30.0	0	8486	0	8656
2	1155	0.10	0.14	0.30	0.59	39	4.4	4.1	5074	4736	9810
3	2406	0.01	0.59	0.20	0.80	21	0.15	8.7	356	21002	21358
4	3764	0.00	0.33	0.20	0.53	9.7	0	2.5	0	9312	9312
5	5046	0.00	0.09	0.20	0.29	5.7	0	0.44	0	2241	2241
6	6164	0.00	0.02	0.20	0.22	4.3	0	0.08	0	471	471
7	7090	0.00	0.00	0.20	0.20	3.4	0	0	0	0	0
						Total	55.9	15.8	14086	37762	51848

b) Closure of beach seine fishery:

age gr. t	mean wgt. (g) W	beach seine FB	gill net FG	nat. mort. M	tot. mort. Z	stock num-ber N	beach seine catch CB	gill net catch CG	beach seine yield YB	gill net yield YG	total yield YB+YG
0	8	0.00	0.00	2.00	2.05	1000	0	0	0	0	0
1	283	0.00	0.00	0.80	1.20	135	0	0	0	0	0
2	1155	0.00	0.14	0.30	0.59	61	0	6.9	0	7955	7955
3	2406	0.00	0.59	0.20	0.80	39	0	16.0	0	38435	38435
4	3764	0.00	0.33	0.20	0.53	17.8	0	4.6	0	17137	17137
5	5046	0.00	0.09	0.20	0.29	10.5	0	0.8	0	4124	4124
6	6164	0.00	0.02	0.20	0.22	7.8	0	0.14	0	866	866
7	7090	0.00	0.00	0.20	0.20	6.3	0	0	0	0	0
						Total	0	28.4	0	68517	68517

Although total yield increased in the case of closure of the beach seine fishery, a closure of this fishery without considering the socio-economic aspects is not recommended.

Exercise 5.4 Jones' length based cohort analysis

Worksheet 5.4

lower limit length group		number caught (mill.)	number of sur-vivors	exploi-tation rate	fishing mort.		total mort.
L1	X(L1,L2)	C(L1,L2)	N(L1)	F/Z	F		Z
11.18	1.1854	2.81	119.82	0.08	0.32		4.22
18.55	1.1047	1.30	82.90	0.08	0.34		4.24
22.15	1.1035	2.96	66.75	0.20	0.99		4.89
25.27	1.0858	3.18	52.13	0.29	1.62		5.52
27.58	1.0596	2.00	41.29	0.31	1.77		5.67
29.06	1.0806	1.89	34.89	0.28	1.51		5.41
30.87	1.1175	1.78	28.13	0.25	1.28		5.18
33.16	1.1949	0.98	20.93	0.14	0.63		4.53
36.19	1.4331	0.63	13.84	0.08	0.36		4.26
40.50	-	0.63	6.30	0.10	0.43	a)	4.33

a) F(40.5) =3.9 * 0.1/(1 - 0.1) = 0.43

The cumulated catch curve (Exercise 4.4.6) gave a Z/K value of about 3. From this we have Z = 3 * 2.6 = 7.8; F = Z - M = 7.8 - 3.9 = 3.9; exploitation rate, F/Z = 3.9/7.8 = 0.5

Exercise 5.5 A predictive length based model (Thompson and Bell analysis)

Worksheet 5.5

length L1-L2	F(L1,L2)	N(L1)	mean biomass	catch C(L1,L2)	YIELD(L1,L2)	VALUE
10-15	0.03	1000	6.47	9.94	0.19	0.19
15-20	0.20	890.56	17.02	63.54	3.40	3.40
20-25	0.40	731.70	31.97	112.28	12.79	19.18
25-30	0.70	535.20	45.18	152.08	31.62	47.44
30-35	0.70	317.95	50.39	102.75	35.27	70.55
35-40	0.70	171.15	48.27	64.08	33.79	67.59
40.00	0.70	79.60	61.10	55.72	42.77	85.55
	Total		260.44	1120.84	159.86	293.91

Exercise 5.5a A predictive length based model (Yield curve, Thompson and Bell analysis)

Worksheet 5.5a

length L1-L2	F(L1,L2)	N(L1)	mean biomass	catch C(L1,L2)	YIELD(L1,L2)	VALUE
10-15	0.06	1000	6.44	19.79	0.38	0.38
15-20	0.40	881.22	16.25	121.30	6.50	6.50
20-25	0.80	668.94	27.08	190.22	21.66	32.50
25-30	1.40	407.39	29.97	201.75	41.95	62.93
30-35	1.40	162.40	22.02	89.80	30.82	61.65
35-40	1.40	53.36	12.56	33.36	17.59	35.19
40.00	1.40	12.84	5.80	10.57	8.12	16.24
	Total		120.13	1333.63	127.05	215.41

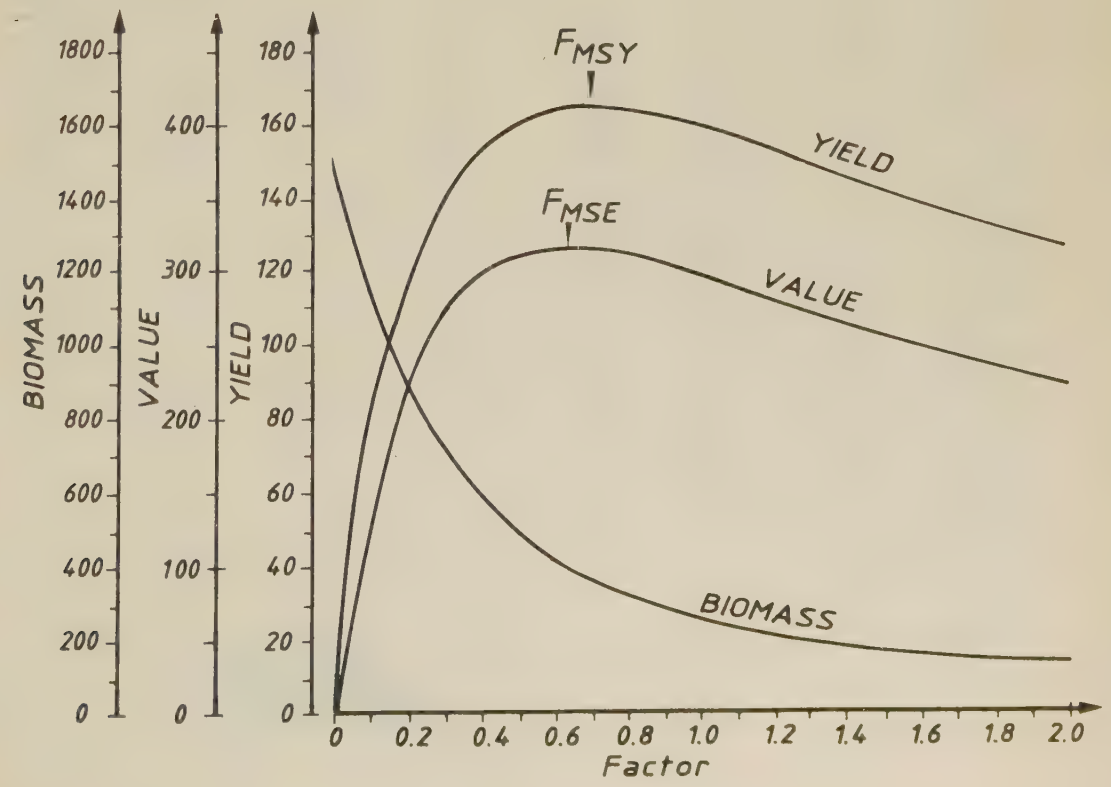


Fig. 18.5.5a

Exercise 6.1.1 A mathematical model for the selection ogive

L50% = 13.6: S1 = 13.6 * ln3/(14.6-13.6) = 14.941
L75% = 14.6: S2 = ln3/(14.6-13.6) = 1.0986

L	11	12	13	14	15	16	17	18
S(L)	0.05	0.15	0.34	0.61	0.82	0.93	0.98	0.99

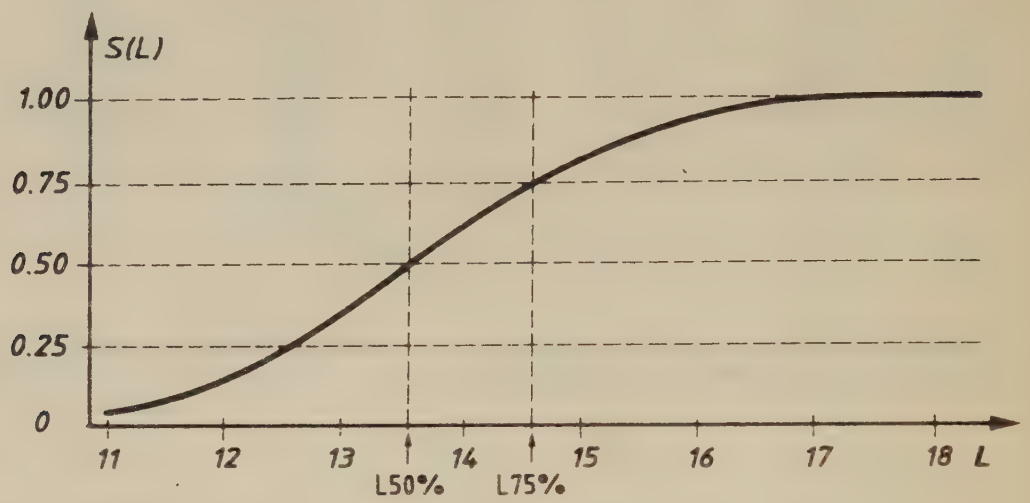


Fig. 18.6.1.1

Exercise 6.1.2 Estimation of the selection ogive from a catch curve

Worksheet 6.1.2

A	B	C	D	E	F	G	H
L1-L2 length group	t X	/\t	C(L1,L2)		S	Y	S
6- 7	0.56	0.102	3	3.38	0.0001	9.07	not used
7- 8	0.67	0.109	143	7.18	0.0081	4.81	0.02
8- 9	0.78	0.116	271	7.76	0.0229	3.75	0.02
9-10	0.90	0.125	318	7.86	0.041	3.15	0.04
10-11	1.03	0.134	416	8.04	0.087	2.58	0.08
11-12	1.17	0.146	488	8.11	0.168	1.60	0.18
12-13	1.32	0.160	614	8.25	0.362	0.67	0.36
13-14	1.49	0.177	613	8.15	0.666	-0.69	0.62
14-15	1.67	0.197	493	7.83	1.020	-	0.83
15-16	1.88	0.223	278	7.13	-	-	0.95
16-17	2.12	0.257	93	5.89	-	-	0.99
17-18	2.40	0.303	73	5.48	-	-	1.00
18-19	2.74	0.370	7	2.94	-	-	1.00
19-20	3.15	0.473	2	1.44	-	-	1.00
20-21	3.70	0.659	2	1.11	-	-	1.00
21-22	4.53	1.094	0	-	-	-	1.00
22-23	6.19	4.094	1	-1.40	-	-	1.00
23-24	-	-	1	-	-	-	1.00

K = 0.59 per year, L_∞ = 23.1 cm, t_o = -0.1 year

Selection regression : 8.808 (=T1) -6.238 (=T2)
t50% : 8.808/6.258 = 1.412
t75% : (ln3 + 8.808)/6.258 = 1.588
L50% : 13.6 cm
L75% : 14.6 cm

Exercise 6.5 Using a selection curve to adjust catch samples

L50% = 13.6: S1 = 13.6 * ln3/(14.6-13.6) = 14.941
L75% = 14.6: S2 = ln3/(14.6-13.6) = 1.0986

Worksheet 6.5

Length group	mid-point	observed biased sample	selection ogive S	estimated unbiased sample
6- 7	6.5	3	0.00041	7326
7- 8	7.5	143	0.00123	116491
8- 9	8.5	271	0.00367	73769
9-10	9.5	318	0.01094	29066
10-11	10.5	416	0.03212	12952
11-12	11.5	488	0.09054	5390
12-13	12.5	614	0.2300	2670
13-14	13.5	613	0.4726	1297
14-15	14.5	493	0.7288	676
15-16	15.5	278	0.890	312
16-17	16.5	93	0.960	97
17-18	17.5	73	0.986	74
18-19	18.5	7	0.995	7
19-20	19.5	2	0.998	2
20-21	20.5	2	0.999	2
21-22	21.5	0	1.000	0
22-23	22.5	1	1.000	1
23-24	23.5	1	1.000	1

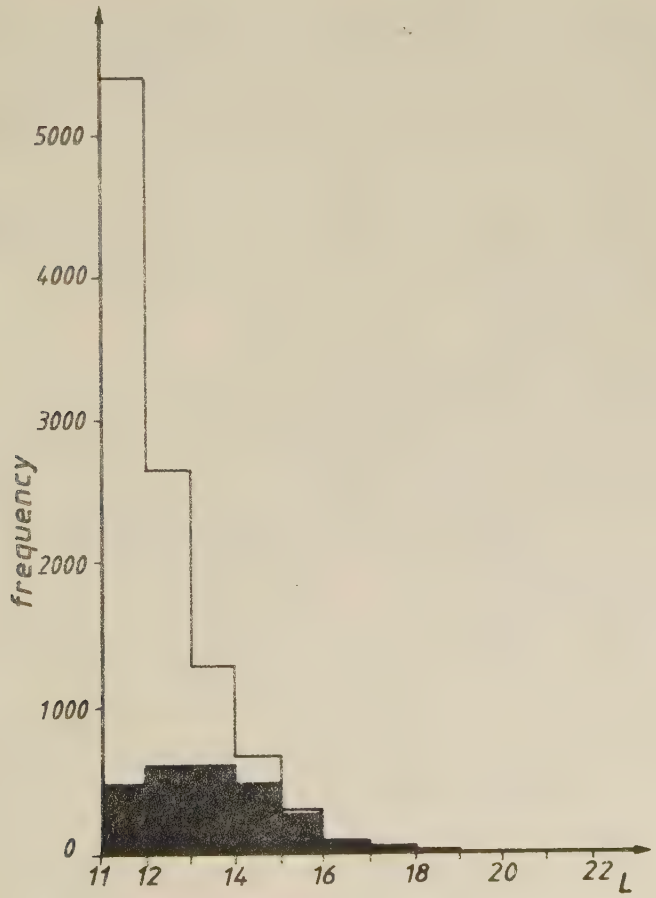


Fig. 18.6.5

Exercise 8.3 The yield per recruit model of Beverton and Holt (Yield per recruit, biomass per recruit as a function of F)

Worksheet 8.3

F	Tc = Tr Y/R	B/R	Tc = 0.3 Y/R	B/R	Tc = 1.0 Y/R	B/R
0.0	0.00	8.28	0.00	8.00	0.00	4.53
0.2	1.36	6.81	1.33	6.67	0.79	3.96
0.4	2.28	5.71	2.26	5.65	1.41	3.51
0.6	2.91	4.85	2.92	4.86	1.89	3.15
0.8	3.34	4.18	3.39	4.24	2.28	2.85
1.0	3.64	3.64	3.73	3.73	2.60	2.60
1.2	3.84	3.20	3.98	3.31	2.86	2.39
1.4	3.97	2.84	4.15	2.97	3.08	2.20
1.6	4.06	2.54	4.28	2.68	3.27	2.05
1.8	4.11	2.28	4.38	2.43	3.43	1.91
2.0	4.14	2.07	4.44	2.22	3.57	1.79
2.2	4.15 *	1.88	4.49	2.04	3.69	1.68
2.4	4.14	1.73	4.51	1.88	3.80	1.58
2.6	4.13	1.59	4.53	1.74	3.89	1.50
2.8	4.10	1.47	4.54	1.62	3.98	1.42
3.0	4.08	1.36	4.54 *	1.51	4.05	1.35
3.5	4.00	1.14	4.52	1.29	4.21	1.20
4.0	3.91	0.98	4.48	1.12	4.33	1.08
4.5	3.82	0.85	4.44	0.99	4.42	0.98
5.0	3.74	0.75	4.39	0.88	4.50	0.90
100.0	2.39	0.02	3.35	0.03	5.15 *	0.05

*) MSY/R

MSY increases when Tc increases, because more fish survive to a large size before they are caught. From age 0.2 years to age 1.0 years the biomass production caused by individual growth exceeds the loss caused by the death process. This, of course, is not true for any high value of Tc. If, for example, Tc would be larger than the lifespan of the species in question, no fish would be caught.

A: (Tc = 0.2) MSY/R = 4.15 (indicated by "*" in the Table)

B: (Tc = 0.3) MSY/R = 4.54

C: (Tc = 1.0) MSY/R = 5.15

For F = 1 the Y/R is 3.64 (curve A), 3.73 (curve B) or 2.60 (curve C).

Thus, irrespective of the actual mesh size in use an increased yield is expected for an increase of effort (F).

The smaller the actual mesh size the smaller the gain in yield from an effort increment.

Exercise 8.4 Beverton and Holt's relative yield per recruit concept

Worksheet 8.4

E	Lc = 118 cm (Y/R)'	Lc =150 cm (Y/R)'	(F)
0	0	0	0
0.1	0.019	0.022	0.020
0.2	0.035	0.043	0.045
0.3	0.048	0.062	0.077
0.4	0.059	0.079	0.120
0.5	0.067	0.093	0.180 = M
0.6	0.071	0.105	0.270
0.7	0.071 *	0.112	0.42
0.8	0.068	0.116	0.72
0.9	0.063	0.117 *	1.62
1.0	0.056	0.114	∞

*) relative MSY/R

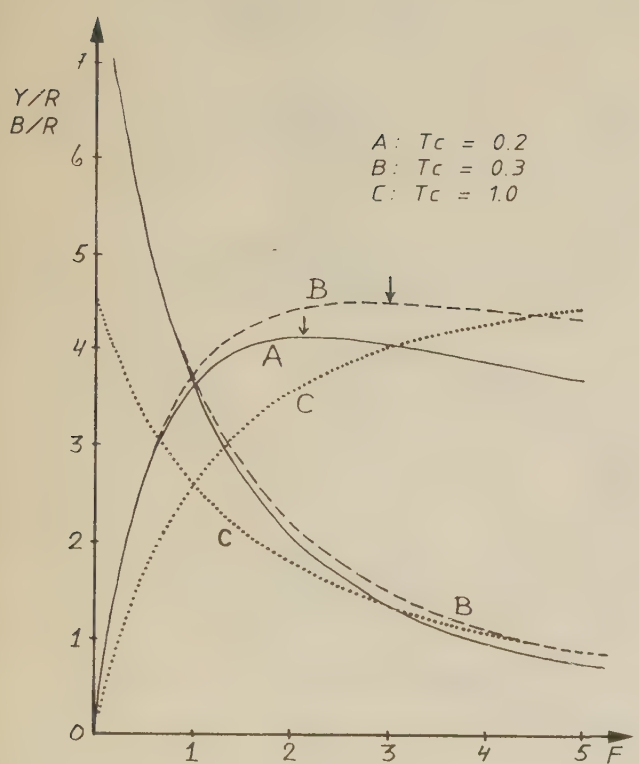


Fig. 18.8.3

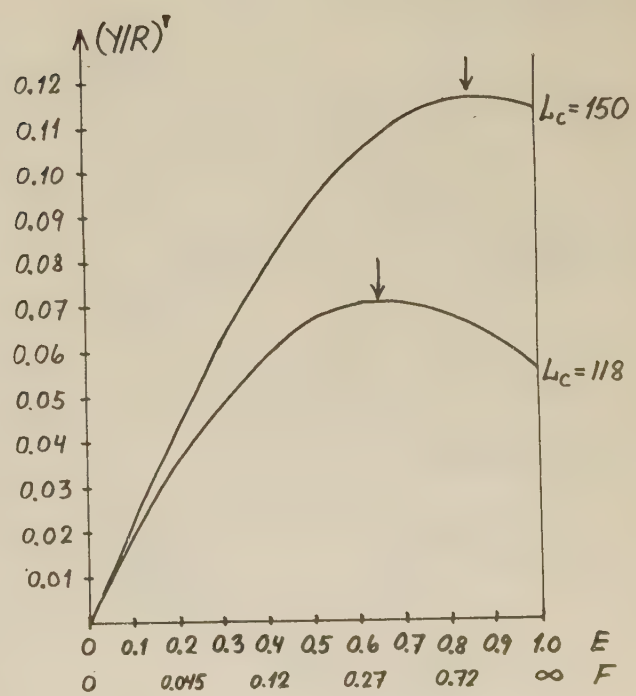


Fig. 18.8.4

Exercise 9.1 The Schaefer model and the Fox model

Worksheet 9.1

year i	yield (tons headless) Y(i)	effort (boat days) f(i) x	SCHAEFER Y/f y	FOX ln(Y/f) Y
1969	546.7	1224	447	6.103
1970	812.4	2202	369	5.911
1971	2493.3	6684	373	5.922
1972	4358.6	12418	351	5.861
1973	6891.5	16019	430	6.064
1974	6532.0	21552	303	5.714
1975	4737.1	24570	193	5.263
1976	5567.4	29441	189	5.242
1977	5687.7	28575	199	5.293
1978	5984.0	30172	198	5.288
mean value :		17286	305.2	5.666
standard deviation:		11233	102.9	0.3558
intercept (Schaefer: a, Fox: c) :			444.6	6.1508
slope (Schaefer: b, Fox: d) :			-0.008065	-0.000028043
variance of slope:				
$sb^2 = ((sy/sx)^2 - b^2)/(10-2)$ *) :			$2.361 * 10^{-6}$	$2.7113 * 10^{-11}$
standard deviation of slope, sb *) :			0.0015364	0.000005207
confidence limits of slope:				
b + t(n-2) sb upper :			-0.0116	-0.00004007
lower :			-0.0045	-0.00001601
variance of intercept:				
$sa^2 = sb^2 [sx^2 (n-1)/n + x^2)$ *) :			973.4	0.01152
standard deviation of intercept :			31.20	0.1073
confidence limits of intercept :				
a + t(n-2) sa *) upper :			372	5.90
lower :			517	6.40
MSY: Schaefer: $-a^2/(4b)$:			6128 tons	6154 tons
Fox : $-(1/d) \exp(c-1)$				
fMSY: Schaefer: $-a/(2b)$:			27565 boat days	35660 boat days
Fox : $-1/d$				

*) a,b replaced by c,d for the Fox-model

Worksheet 9.1a

f	equilibrium yield (tons) Schaefer	Fox
5000	2021	2039
10000	3640	3544
15000	4854	4620
20000	5666	5354
25000	6074	5817
27565	6128 = MSY	
30000	6080	6068
35000	5681	6153
35660		6154 = MSY
40000	4880	6112
45000	3675	5976

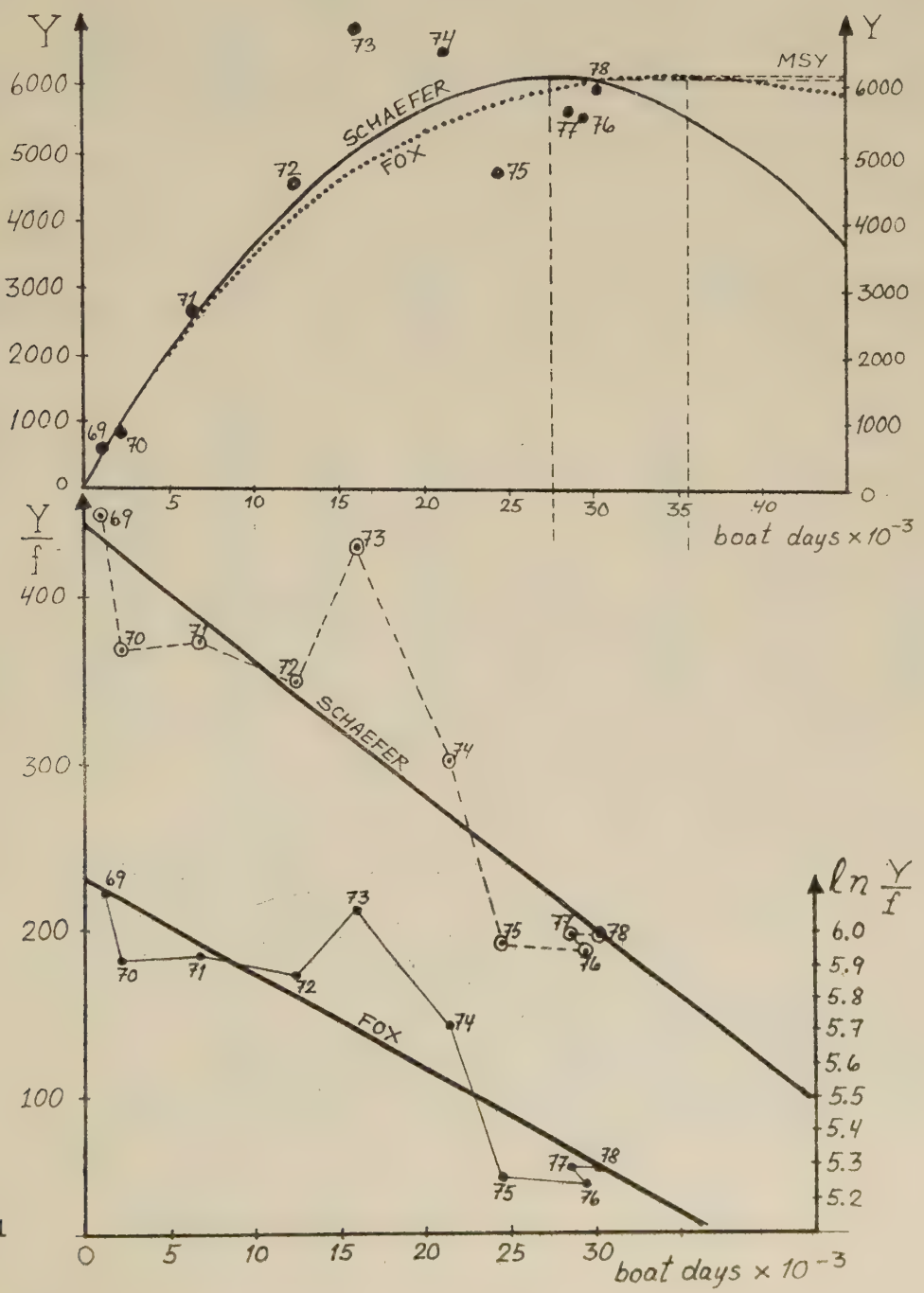


Fig. 18.9.1

Exercise 13.8 The swept area method, precision of the estimate of biomass, estimation of MSY and optimal allocation of hauls

Worksheet 13.8

STRATUM I:

haul no. i	Cw/t kg/h	VESSEL speed knots VS	VESSEL course deg. dirV	TRAWL w.spr. m h*x2	CURRENT speed knots CS	CURRENT dir. deg. dirC	dist. nm. D	area swept a	Cw/a (Ca) kg/sq.nm.
1	7.0	2.8	220	18	0.5	90	2.508	.02438	287.2
2	7.0	3.0	210	16	0.5	180	3.442	.02974	235.4
3	5.0	3.0	200	17	0.3	135	3.139	.02881	173.6
4	4.0	3.0	180	18	0.4	230	3.271	.03180	125.8
5	1.0	3.0	90	17	0.5	270	2.500	.02295	43.6
6	4.0	3.0	45	18	0.4	160	2.854	.02774	144.2
7	9.0	3.5	25	18	0.4	200	3.102	.03015	298.5
8	0.0	3.0	210	18	0.3	300	3.015	.02930	0.0
9	0.0	3.5	0	18	0.4	0	3.900	.03790	0.0
10	14.0	2.8	45	18	0.6	0	3.252	.03161	442.9
11	8.0	3.0	120	18	0.3	300	2.700	.02624	304.9
								mean	186.9

STRATUM II:

haul no. i	Cw/t kg/h	VESSEL speed knots VS	VESSEL course deg. dirV	TRAWL w.spr. m h*x2	CURRENT speed knots CS	CURRENT dir. deg. dirC	dist. nm. D	area swept a	Cw/a (Ca) kg/sq.nm.
12	42.0	4.0	30	17	0.5	160	3.698	.03395	1237.1
13	98.0	3.3	215	17	0.4	90	3.287	.03017	3248.1
14	223.0	3.9	30	17	0.0	0	3.900	.03580	6229.2
15	59.0	3.8	35	17	0.3	180	3.558	.03266	1806.3
16	32.0	3.5	210	17	0.5	270	3.775	.03465	923.5
17	6.0	2.8	210	17	0.5	330	2.587	.02374	252.7
18	66.0	3.8	45	17	0.5	30	4.285	.03933	1678.0
19	60.0	4.0	30	18	0.5	180	3.576	.03475	1726.5
20	48.0	4.0	210	18	0.5	180	4.440	.04315	1112.3
21	52.0	3.8	20	18	0.4	180	3.427	.03331	1561.3
22	48.0	4.0	30	18	0.5	190	3.534	.03435	1397.4
23	18.0	3.0	210	18	0.3	190	3.474	.03377	533.1
								mean	1808.8

stratum	n number of hauls	$\overline{Ca}$	s	$s/\sqrt{n}$	t(n-1)	confidence limits for $\overline{Ca}$
1	11	186.9	141.6	42.7	2.23	[92 , 282]
2	12	1808.8	1581.4	456.5	2.20	[804 , 2813]

For stratum I and II combined: A = A1 + A2 = 77 sq. nm.

$\overline{Ca}$ = (24 * 186.9 + 53 * 1808.0)/77 = 1302.7 kg/sq.nm. (cf. Eq. 13.7.5).
Total biomass of whole area: B = 1302.7 * 77/0.5 = 201 tons.

From Eq. 9.3.1: MSY = 0.5 * 0.6 * 201 = 60 tons/year.

Worksheet 13.8a (for plotting graph)

number of hauls n	t(n-1)	stratum I ϵ *)	stratum II ϵ **)
5	2.78	0.94	1.09
10	2.26	0.54	0.63
20	2.09	0.36	0.41
50	2.01	0.22	0.25
100	1.98	0.15	0.18
200	1.97	0.11	0.12

*) $\epsilon = \frac{s * t(n-1)}{\overline{Ca} * \sqrt{n}}$ with s = 141.6 and $\overline{Ca}$ = 186.7

**) with s = 1581.4 and $\overline{Ca}$ = 1808.8

Worksheet 13.8b (optimum allocation)

stratum	s	A	A * s	A * s/ΣA * s	200 * A * s/ΣA * s
I	141.6	24	3398	0.039	8
II	1581.4	53	83814	0.969	192
Total			87212		200

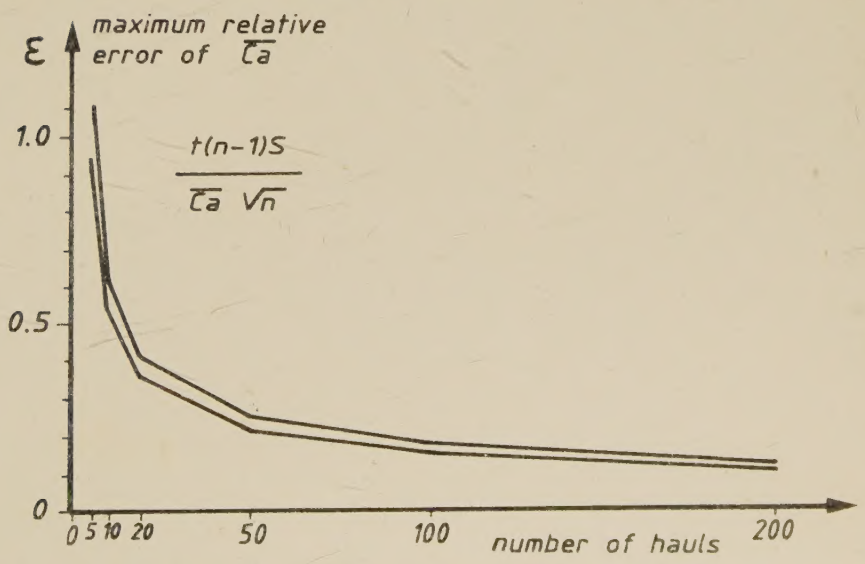


Fig. 18.13.8

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